UNIVERSAL
Machinists' Handbook

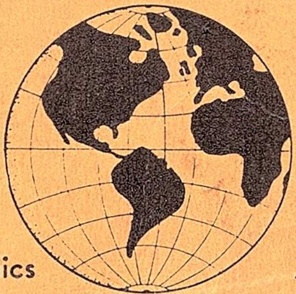
A Practical Handbook For

Machinists

Engineers

Draftsmen

Aviation Mechanics



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UNIVERSAL MACHINISTS HANDBOOK

Saves Time

ELIMINATES ERRORS — ARRANGED FOR QUICK AND EASY REFERENCE

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A PRACTICAL HANDBOOK

for Today's

Machinists • Engineers • Draftsmen Aviation Mechanics • Students • Tool Makers • Pattern Makers • Auto Mechanics • And all others in Mechanical, Technical and Allied Fields.

by

CHARLES SHIELDS
MECHANICAL ENGINEER

•

SHIELDS PUBLISHING COMPANY
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PREFACE

One of the greatest needs of technical and mechanical fields today is well trained mechanics and workers who are skilled not only with their hands — but who are also trained to think about their immediate tasks and those further up the line.

This Handbook is meant for both beginners and experienced mechanics alike who are anxious to do their work so well that progress is assured. It offers in simple, technical form, vital time, labor and error saving information — arranged, indexed and cross-referenced in such a way that it can be found quickly and easily.

Actual experience of mechanics, engineers, draftsmen, etc., has dictated what information should be contained in the Universal Machinists Handbook. Every effort has been made to make this one book more valuable and easier to use than the usual bulky volumes necessary to find adequate information.

Over thirty-six years have elapsed since the first edition of this Handbook was offered as a crude blueprint book. During its fifteen editions, many changes have taken place in machines, tools, parts and materials. These changes have made it necessary to add much new data in order to keep it up-to-date. Material no longer vital has been eliminated.

This Fifteenth Edition is completely revised and thoroughly enlarged to cover wider fields of shop activities than ever before. Every effort has been made to give only the best, most modern and practical data used in today's highly developed machine shop and engineering practice.

Suggestions and criticisms from users of this book are always welcome.

THE PUBLISHERS

CHAPTER INDEX CONTENTS

FIFTEENTH EDITION
REVISED and ENLARGED

ALPHABETICAL INDEX

THANKS TO THE CONTRIBUTORS

We wish to thank the following firms for their courteous co-operation and aid in gathering and preparing certain of the new information and tables contained in this edition of the handbook.

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American Leather Belting Ass'n
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Standard Tool Co.
The L. S. Starrett Co.
Thermoid Corp.
Waukesha Motor Co

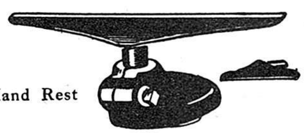
Turning Wood, Fibre and Plastics

Turning wood in a metal working lathe is a very simple matter. Spur and cup centers are substituted for the 60° centers, a hand rest is attached and the lathe is ready for wood turning.

Special pulleys may be used on the motor and countershaft to provide a series of high spindle speeds for wood turning, in addition to the regular speeds for metal work.

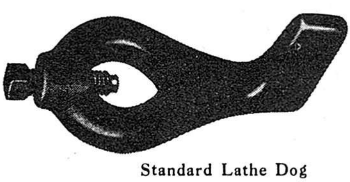
Other materials may be machined as well. Alabaster, Catalin, Bakelite, fibre and other plastics, synthetic resins, etc., may be turned and polished with complete satisfaction.


Wood Turning in a Metal Working Lathe


Hand Rest


Spur Center


Cup Center


Standard Lathe Dog


Safety Lathe Dog

HOW TO TAKE ACCURATE MEASUREMENTS

The ability to take accurate measurements can be acquired only by practice and experience. Careful and accurate measurements are essential to good machine work. All measurements should be made with an accurately graduated steel scale or a micrometer. Never use a cheap steel scale or a wood ruler, as they are likely to be inaccurate and may cause spoiled work.

An experienced mechanic can take measurements with a steel scale and calipers to a surprising degree of accuracy. This is accomplished by developing a sensitive "caliper feel" and by carefully setting the calipers so that they "split the line" graduated on the scale.

Caliper Feel

The accuracy of all contact measurements is dependent upon the sense of touch or feel. The caliper should be delicately and lightly held in the finger tips, not gripped tightly. If the caliper is gripped tightly, the sense of touch is very much impaired

OUTSIDE CALIPERS

Outside calipers are used to measure the diameters of the work being turned. There are three kinds of calipers: Spring Calipers Fig. 1, firm point calipers Fig. 2, and/or "mikes" Fig. 3.

Spring Calipers are provided with a screw and adjusting nut for quick setting to size, whereas the firm joint calipers are set by tapping one leg against a solid object. Both types have their advantages. The spring type is much preferred on small work, while on large diameter work, the solid joint type because of stiffer legs is better.

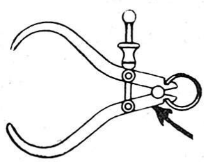


Fig. 1

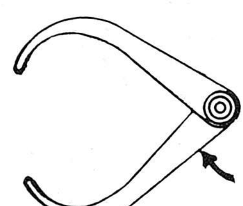


Fig. 2

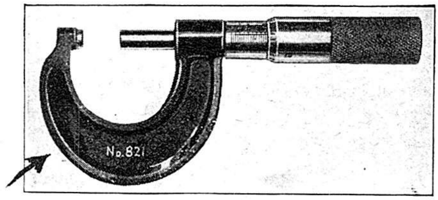


Fig. 3

Continued on next page

TO SET AN OUTSIDE CALIPER

To set calipers to a diameter with the use of a scale in the right hand, using the forefinger to keep the one leg from slipping off end of the scale and adjust the caliper Fig. 4, to the dimension required. Some mechanics become quite expert at setting calipers, acquiring a "feel" that enables them to set calipers to .005 of an inch. In many cases your work will be to reproduce broken parts, and the calipers can be set from the broken part.

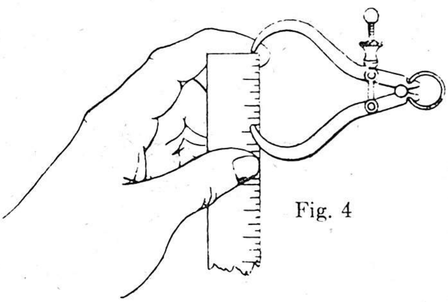


Fig. 4

Be certain, however, that the part is not worn where you set the calipers. Try the calipers at different points to see if the piece is round and that you are not calipering on the smallest diameter. When calipering a piece of work it is best to hold the caliper in a vertical position Fig. 5, with the legs at right angles to the axis of the piece, and adjust to a point where the weight of the calipers will just allow the points to pass over the diameter of the piece. This slight resistance is known as the "feel". Never force the calipers over the piece as the legs will spring, and inaccuracy will result. If you get the same "feel" on the sample as you get on the piece being turned, the diameter will correspond within the closed limits.

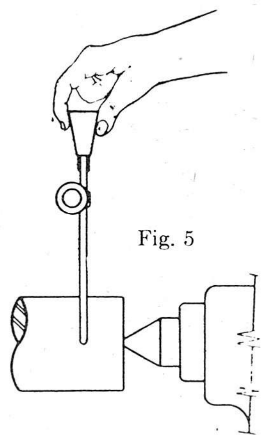


Fig. 5

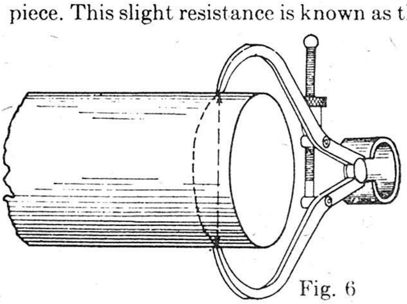


Fig. 6

Never try to caliper a piece revolving in the lathe where accuracy is required. For obtaining the approximate diameter this is permissible, but for accurate dimensions, the lathe should be stopped.

The proper method for measuring with an outside caliper. To measure the diameter of a cylinder is shown in Fig. 6. Hold the caliper at right angles to the center line of the work, and is pushed gently back and forth across the diameter of the cylinder to be measured. The caliper when properly adjusted, it should easily slip over the shaft of its own weight.

INSIDE CALIPER

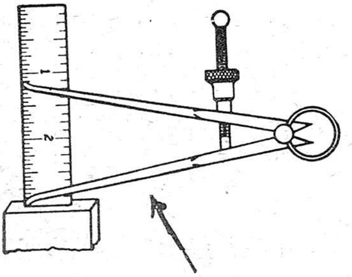


Fig. 7

Inside calipers are used for internal work such as bored and reamed holes and are made both in the spring and firm joint type. In sétting the calipers to a scale, hold the scale against a flat surface, placing one leg against the flat surface and adjusting the other leg to the required dimension, Fig. 7.

If you are boring to accurate dimensions, set a micrometer to the dimension required and transfer this to your inside caliper. This can be done best by holding the micrometer in the left hand and the inside caliper in the right hand Fig. 8, and adjusting it until the proper "feel" is obtained. The adjustment is obtained by rocking the caliper in a vertical plane between the axis of the anvil and spindle of the micrometer. When calipering a hole, Fig. 9, set one leg of the inside micrometer caliper in the hole, pivoting the caliper in a vertical plane and adjusting until the other leg enters the hole. By rocking and adjusting the caliper, the proper "feel," across the largest diameter can be obtained. If the calipers are forced into the hole, the legs will spring and an inaccurate measurement will be obtained. When boring a hole to fit a shaft or turning a shaft to fit a hole, it is necessary to transfer measurement from outside to inside calipers and vice versa. This can be done by holding the outside caliper in the left hand supporting it between the thumb and forefinger, Fig. 10, with the second finger of the left hand supporting the lower legs of the outside and inside calipers to be set. The inside calipers are held in the right hand with the adjusting nut between the thumb and forefinger. By rocking the inside caliper in a vertical plane and adjusting it until the proper "feel" is obtained, accurate transfer from one to the other can be made.

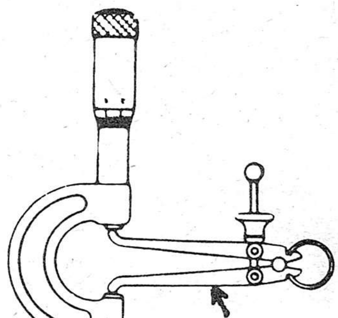


Fig. 8

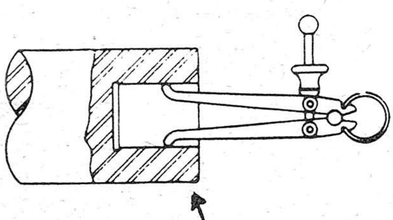


Fig. 9

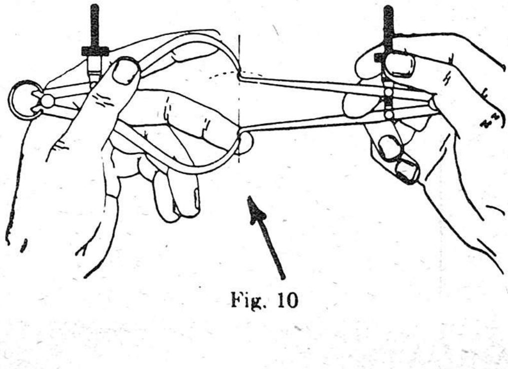


Fig. 10

READING A HEIMAPHRODIATE CALIPER

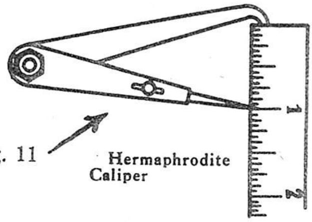


Fig. 11

How to read a Heimaphrodiate Caliper shown in Fig. 11, is set from the end of the scale exactly the same as the outside caliper.

HOW TO READ AND HOLD A MICROMETER

The Micrometer Caliper, Fig. 12, is used for measuring to very close dimensions, its graduations reading to one-thousandth of an inch. It consists of five principal parts, the frame "A", the Anvil "B", the Spindle "C", the Sleeve "D", and the Thimble "E". The Spindle "C" has a thread cut on it which fits a tapped hole in the Sleeve "D" that is not exposed. The threads are cut 40 to the inch

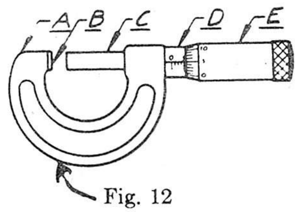


Fig. 12

so that exactly one revolution of 15. The Thimble "E" advances the Spindle "C" one-fortieth of an inch, or twenty-five thousandths (.025) which is the gap between the Anvil "B" and the Spindle "C", the measuring point. The Sleeve "D" is graduated with 40 divisions to the inch and numbered 0—1—2 & to 10, a number at every fourth division, so that the figure one, or four divisions, represents 4 × .025 of an inch (1/40) or one-tenth of an inch (.100). The number last showing on the Sleeve "D" when the mike is set on a diameter is the first number after the decimal point is your reading. On the bevel edge of the Thimble "E" are twenty-five graduations, each of these representing one-thousandth of an inch. In illustration Fig. 13, you have showing on the sleeve seven graduations representing .025 each, equalling 7 × .025 or .175 and three graduations on the thimble beyond the zero (0) mark, each representing .001 so that the caliper is set at .175″ plus .003″, equalling .178″, or for greater convenience

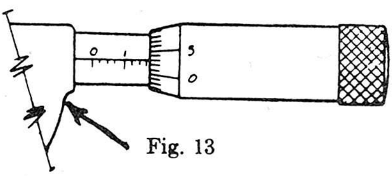


Fig. 13

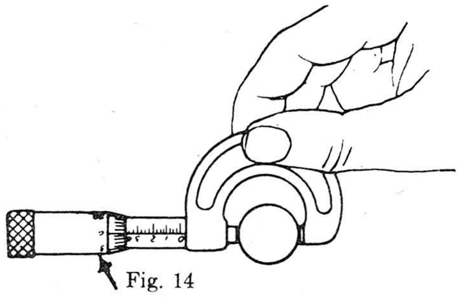


Fig. 14

read the highest number showing on the sleeve, one-tenth (.1); beyond this read the number of graduations showing 3 which equals 3 × .025″ or .075, then add to this graduations on the Thimble, three making .178. For convenience in using micrometers tables of fraction and decimal equivalents, also English and Metic equivalents, will be found in this book.

When calipering with micrometers the same "feel" is necessary as with the other calipers, and they should not be forced over the work.

Hold the "mikes" between the forefinger and the thumb as shown in Fig. 14, and let the weight carry them over the diameter.

SUGGESTIONS FOR HOLDING MICROMETER CALIPERS

Do not caliper with the piece revolving as this will damage the anvil and the end of the spindle. Check up the "mikes" occasionally with a reference disc (standard gauge) to see that they register correctly.

How to read An Inside Micrometer Caliper Outside Micrometers Fig. 15, are manufactured for diameters of one-half inch and up. They are read the same as outside Micrometers. A few suggestions for holding Micrometer Calipers are given in Figs. 16, 17, 18, 19, 20 and 21.

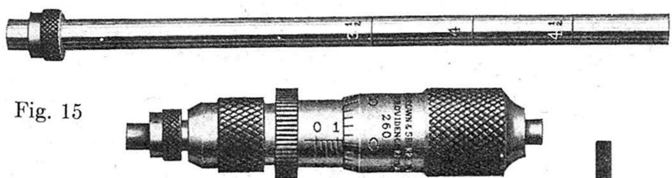


Fig. 15

Inside Micrometer

Fig. 16

Outside Micrometer Caliper Measuring the Diameter of Work in the Lathe.

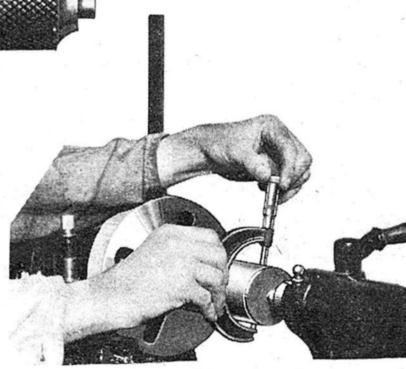


Fig. 16

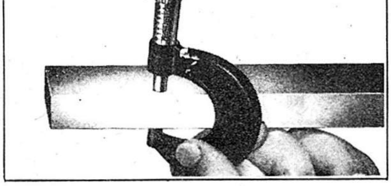


Fig. 17

Fig. 17

In using a one inch Micrometer for small work, hold the tool in one hand, turning the thimble with the same hand, as shown. This permits freedom of the other hand for holding the work. In measuring larger or stationary work, the frame should be held securely in one hand while the other hand turns the thimble.

In using a larger micrometer, the frame should be held securely in one hand at a point where its weight is supported most conveniently without cramping the measuring surfaces. The other hand should turn the thimble.

Fig. 18

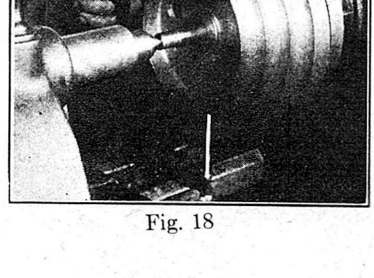


Fig. 18

Fig. 19

Using an Internal Micrometer Caliper Measuring the Diameter of a Machined Hole.

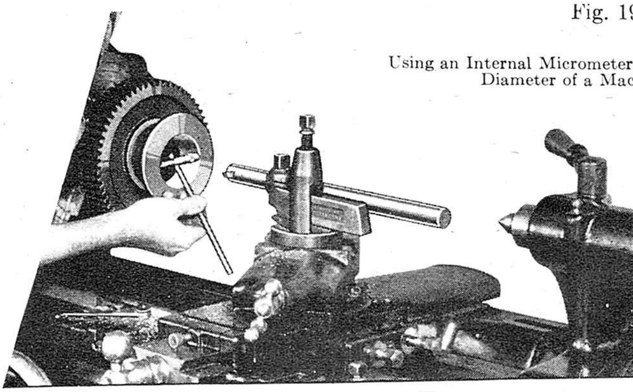


Fig. 19

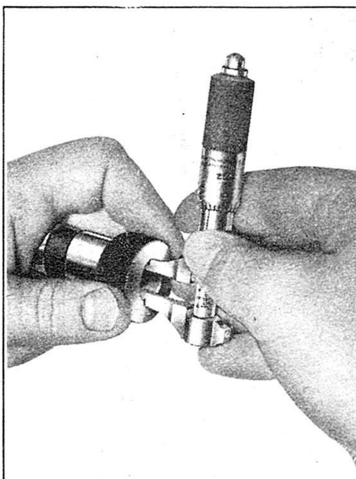


Fig. 20

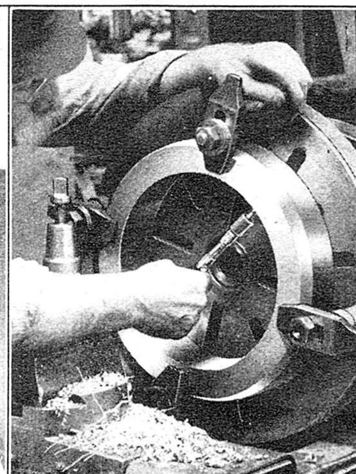


Fig. 21

Small internal measurements are taken easily and accurately by Inside Micrometer Caliper.

Fig. 20

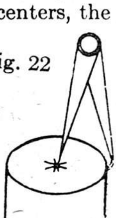
For quick, accurate measurements, Tubular Inside Micrometers find many uses.

Fig. 21

CENTERING WORK

Lathe work may be divided into two principal classes, namely, work machined between centers and work machined in chucks. Bar or shaft work is done between the centers, the piece to be turned having been previously centered.

Fig. 22



There are many ways of centering a piece of material. In large production shops this work is done in a centering machine. In small shops the lathe operator usually centers his own work. The first thing to do is to find the center on each end of the pieces. This can be done by using hermaphrodite calipers. Set the caliper to about one-half the diameter of the piece, chalk the end of the piece so the scribe marks can be seen, and scribe four arcs, one from each quarter of the circumference (Fig. 22). The center of the piece lies between the four arcs. Mark the center thus located with a center punch. Perform the same operation on the other end of the piece and it is ready to have the centers drilled.

The center of a piece can also be located by the use of a center head on a combination square. Draw two lines at about right angles to each other. Where they bisect will be the center of the piece (Fig. 23).

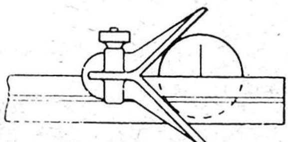


Fig. 23

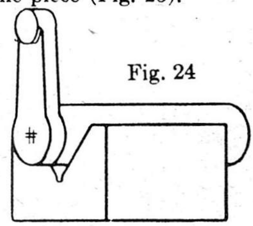


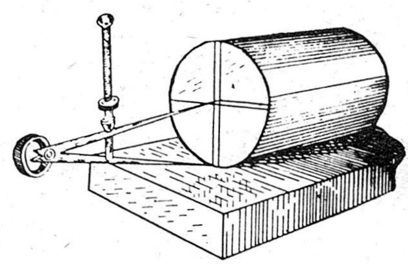
Fig. 24

To center irregularly shaped pieces such as a drop forged brake lever, lay the piece in a V-block (Fig. 24) on a plane surface and use a surface gauge for scribing the lines on each end. First set the gauge to the approximate height of the center and scribe a line. Turning the piece, scribe three more lines, each at about 90 degrees. The center of the piece is in the center of the square formed by the scribed lines.

After the center has been found on each end of the piece and it has been center-punched, the actual drilling of the center can be done under a drill press or in the lathe itself.

Locating Center Holes

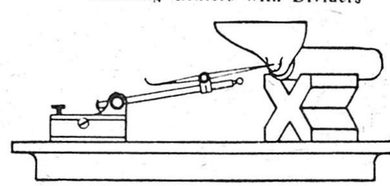
There are several good methods for accurately locating the center holes which must be drilled in each end of the work before it can be mounted on the lathe centers for machining.



Locating Centers with Dividers

Divider Method

Chalk the ends of the shaft, set the dividers to approximately one-half the diameter of the shaft, and scribe four lines across each end, as shown.



Centering an Irregular Shape

Centering Irregular Shapes

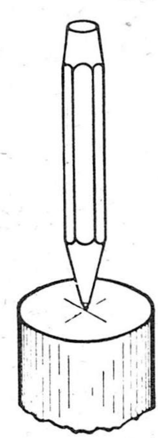
Work that is irregular in shape may be centered with a surface gauge and V-block, as shown.

Bell Center Punch

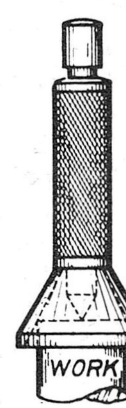
The bell centering cup is placed over the end of the work and the center punch or plunger is struck a sharp blow with the hammer, automatically locating the center.

Punching the Center

Place the center punch vertically at the center point and tap with a hammer, making a mark sufficiently deep so that the work will revolve on the center points when placed in the lathe.

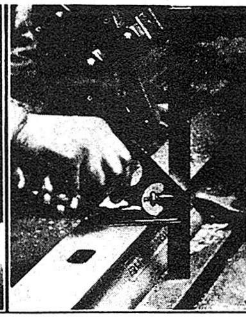


Punching the Center



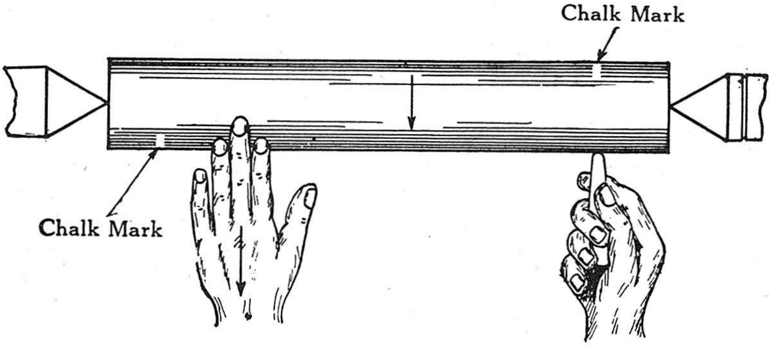
Bell Center Punch

Finding center line of round work is one use for Combination Squares.



A Combination Square makes a very convenient depth gage.

Angles are determined quickly and accurately with a Protractor.

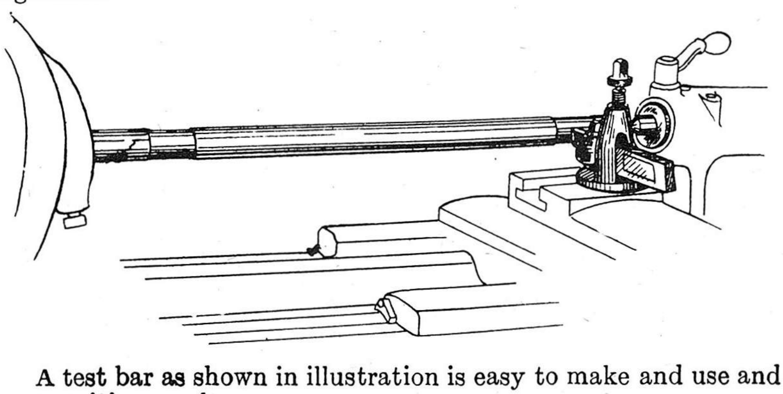


Testing the Accuracy of Center Punch Marks

Alignment of Centers

When turning straight work, try alignment of tailstock center with headstock center to be sure work will not be tapered.

When zero marks are in line on tailstock, top and bottom, centers are approximately in line, but due to the impossibility of seeing an error of .001″ misalignment, it is probable that the work will be tapered if a no more sensitive test is applied to the center alignment.

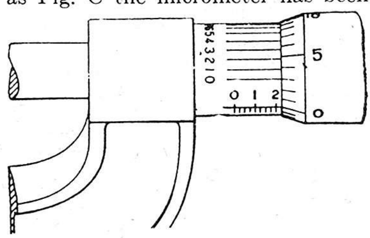


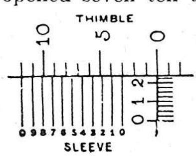
A test bar as shown in illustration is easy to make and use and gives positive results.

Micrometers Graduated to Ten Thousandths

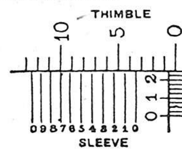
There are eleven parallel lines on the sleeve occupying the same space as ten lines on the thimble; these lines are numbered 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 0. The difference between the width of one of the ten spaces on the sleeve and one of the nine spaces on the thimble is one-tenth of a space on the thimble or one ten thousandth of an inch in the reading of micrometer.

In Fig. B the third line from 0 on thimble coincides with the first line on the sleeve. The next two lines do not coincide by one-tenth of a space on the thimble, the next two marked 5 and 2 are two-tenths apart, and so on. When the micrometer is opened the thimble is turned to the left and each space on the thimble represents a thousandth of an inch. Therefore, when the thimble is turned so that the lines 5 and 2 coincide the micrometer is opened two-tenths of one thousandth or two ten thousandths. If the thimble be turned down further, so that the line 10 coincides with the line 7 on the sleeve as Fig. C the micrometer has been opened seven ten thousandths.





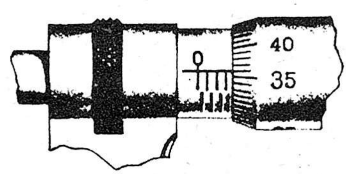
B



C

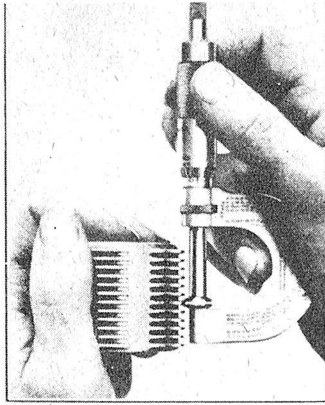
How to Read Micrometers Graduated for Metric Measure

The customary pitch of the screw is ½ mm. Thus, the distance traversed by the screw or spindle during one complete revolution is ½ mm, or .50 mm, and two complete revolutions are required to move the spindle a distance of 1.00 mm. The graduations on the barrel conform to the pitch of the screw. The upper set of graduations, representing mm, is numbered every fifth graduation; the lower set of graduations subdivides each mm division into 2 equal parts. The beveled edge of the thimble is graduated into 50 parts and figured every fifth division 0, 5, 10, 15, 20, 25, 30, etc. When fifty of these graduations have passed the horizontal line on the barrel, the spindle, having made one revolution, has moved .50 mm. Thus, when the spindle moves only far enough to cause one graduation to pass the horizontal line on the barrel, it will have moved 1/50 of .50 mm, or .01 mm. The distance between the graduations on the thimble is great enough to permit half and quarter hundredths of a mm to be readily estimated.

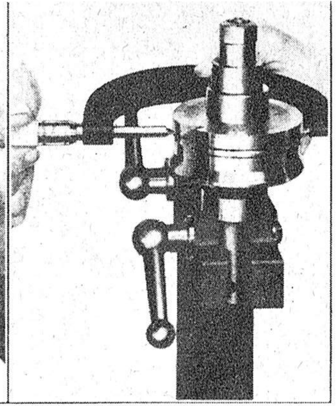


To read—First note the last figure visible on the scale on the barrel representing a whole mm. Note whether or not a half mm division is visible beyond this graduation. Then determine the hundredths mm by the line on thimble coinciding with the horizontal line on the barrel. The mm shown (plus .50 mm if a half mm graduation shows), plus the number of hundredths of a mm, is the reading.

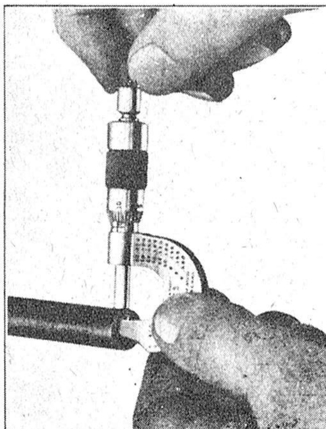
Example:—In cut above, 3 mm graduations are shown; also a ½ mm graduation is visible; on the bevel on the thimble the graduations show 36 divisions from the zero to the line coincident with the line of graduations on the barrel. Then the reading = 3.00 mm + .50 mm + .36 mm = 3.86 mm.



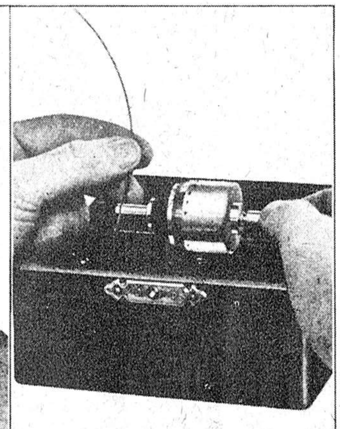
Micrometer Caliper No. 215RS accurately measures the thickness of forms.



Micrometer Caliper No. 218 determines diameters and depths of grooves.

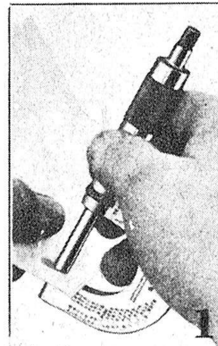


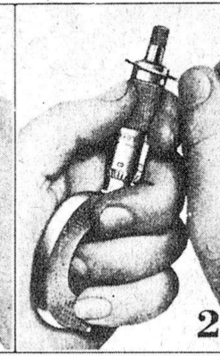
The rounded anvil of No. 225RS permits accurate measurements of thickness of tubing.

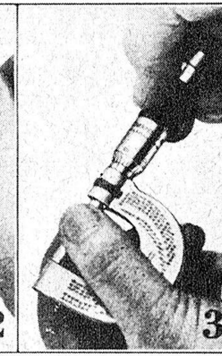


Small parts are measured by ten-thousandths with No. 233RS.

IMPORTANT: Grip micrometer as shown below. Check zero setting after adjustment is made.



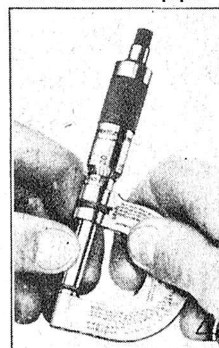


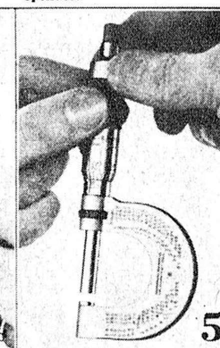


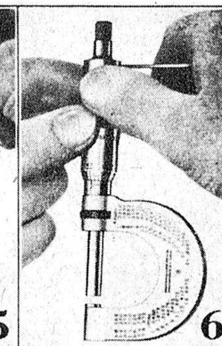
1. Carefully clean the measuring surfaces by pulling a piece of soft paper between the surfaces while the anvil and spindle are in light contact with the paper. Do not use a hard paper.

2. With the anvil and spindle apart, unlock cap with spanner wrench; then tighten cap lightly with fingers to bring slight tension between thimble and spindle.

3. Bring anvil and spindle together by turning spindle and set zero line on thimble to coincide with line on barrel.



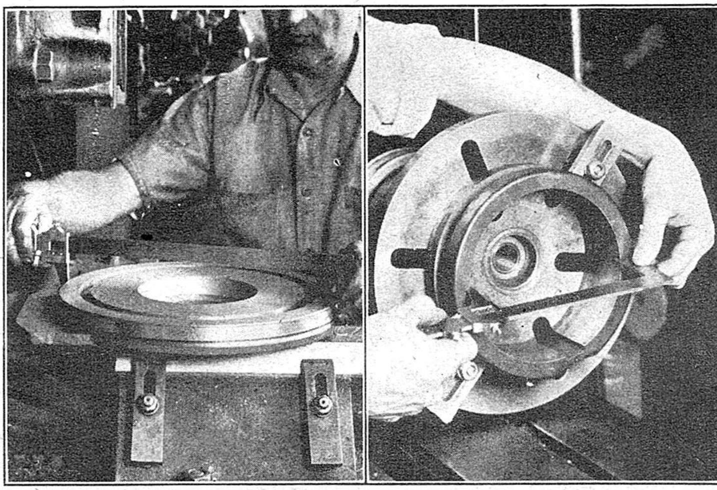




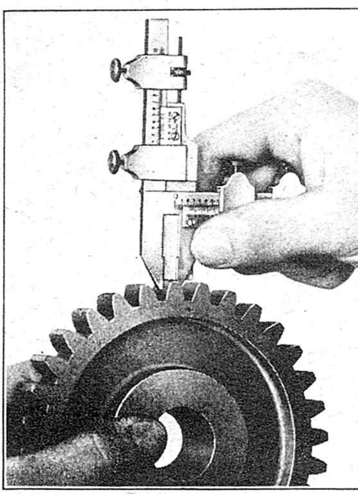
4. Move spindle away from anvil by turning spindle, not by turning thimble.

5. Holding thimble only, tighten cap with fingers. Be careful not to touch frame.

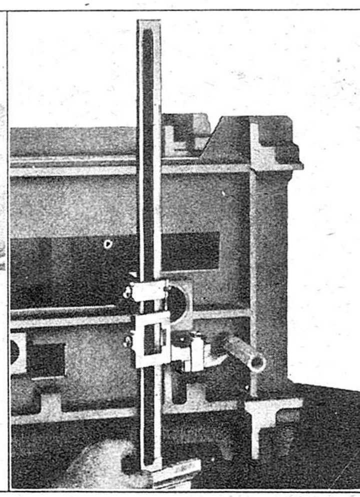
6. Lock cap with wrench, still holding thimble only, and adjustment is complete.



Reliable outside and inside measurements in thousandths of an inch are taken up to 48″ with a Vernier Caliper.

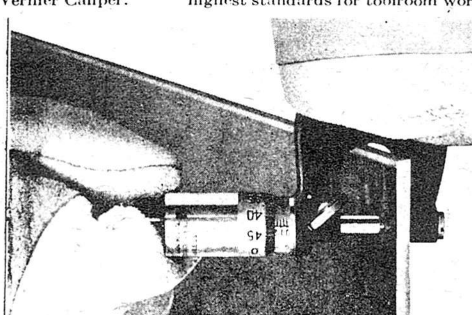


Gear teeth are measured accurately with the Gear Tooth Vernier Caliper.

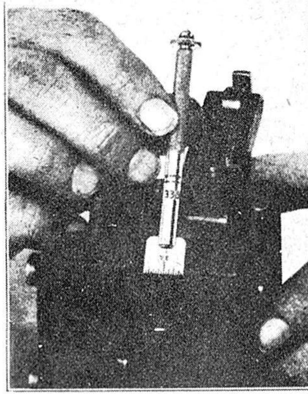


Vernier Height Gages maintain the highest standards for toolroom work.

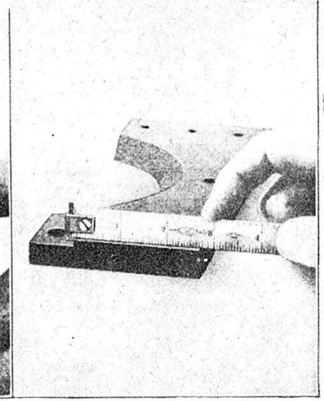
BROWN & SHARPE MFG. CO.



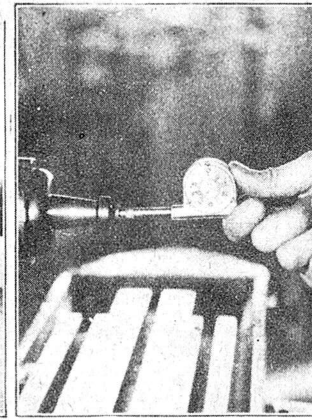
No. 110 meets the severe conditions under which hot and cold sheet metal must be measured.



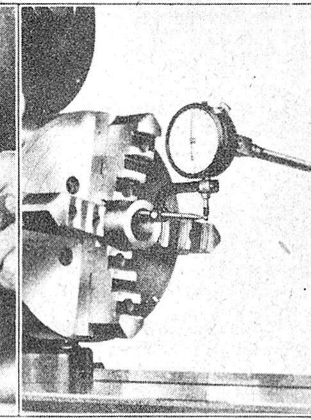
For measuring recesses, a Steel Rule with Holder is often very convenient.



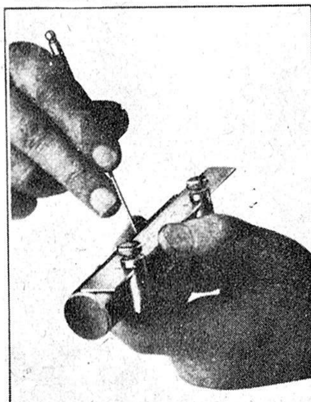
A Brown & Sharpe Hook Rule measures work with a very shallow shoulder.



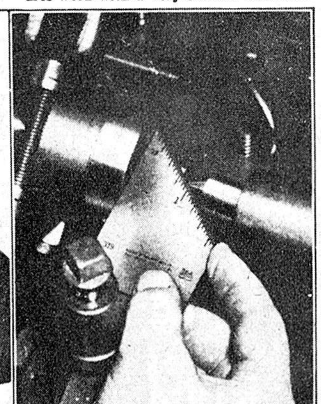
A Speed Indicator is essential for determining the speed of spindles.



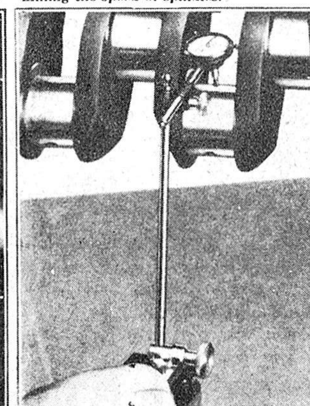
Hole Attachment provides a convenient means for internal testing.



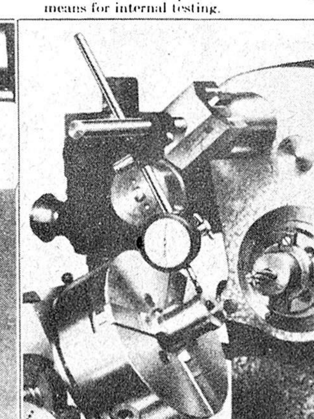
A Tempered Steel Rule used with Key Seat Clamps assures a correct layout.



Graduated angular edge of No. 319 makes possible measurements in limited spaces.



Dial Gage of No. 740 used on No. 621 Surface Gage to test bearings within throws of crankshaft.



Dial Test Indicator No. 744 with Magnetic Base can be used in many places that ordinarily require a special fixture.

Reading the Vernier

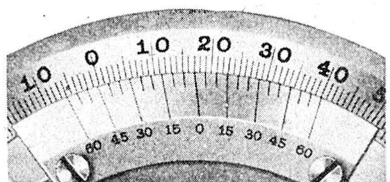
On Universal Bevel Protractor

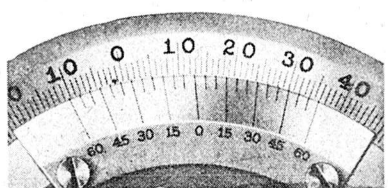
THE Vernier indicates every 5 minutes (5′), or one twelfth of a degree. Each space upon the Vernier is 5 minutes shorter than two spaces on the scale.

When the zero on the Vernier exactly coincides with a graduation on the scale, the reading is in exact degrees, as in upper cut in which the reading is 17° 0′. When the zero graduation of the Vernier does not exactly coincide with a graduation on the scale, the graduation on the Vernier that does coincide with a graduation on the scale indicates the number of 12ths of a degree or 5 minutes to be added to the whole degree reading.

Read off directly from the scale the number of whole degrees between 0 on the scale and 0 on the Vernier. Then count, in the same direction, the number of divisions from the 0 of the Vernier to the first line on the Vernier that coincides with a line on the scale. As each division on the Vernier represents 5 minutes, the number of these divisions multiplied by 5 will be the number of minutes to be added to the whole number of degrees.

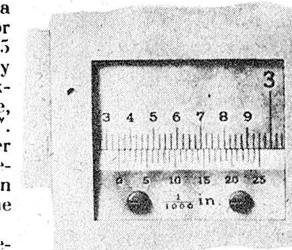
Example: Lower cut shows the zero on the Vernier between 12 and 13 on the scale. Counting to the right from zero on the scale, the zero on the Vernier has therefore moved twelve whole degrees. In the same direction the 10th line of the Vernier, representing 50 minutes (50′), is the line which exactly coincides with a line on the scale. We, therefore, have 50 minutes as indicated by the Vernier, to be added to the reading of twelve degrees on the scale. The reading, then, is 12° 50′.

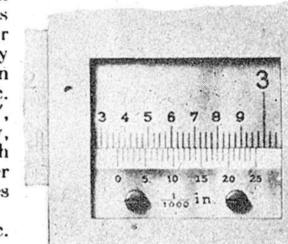




Since the divisions, both on the scale and on the Vernier, are numbered both to the right and left from a basis of zero, any size angle can be measured, and the readings on the scale and on the Vernier, are taken either to the right or left, according to the direction in which the zero on the Vernier is moved.

Reading the Vernier—English Measure





Cuts show the Vernier used with a scale which is graduated into 40ths or .025ths of an inch. The Vernier has 25 divisions which are numbered every 5th division and which equal, in extreme length, 24 divisions on the scale, or $24 \times 1/40'' = 24 \times .025'' = .600''$. Thus, one division on the Vernier equals 1/25 of .600″ = .024″. Therefore, the difference between a division on the Vernier and a division on the scale = .025″ — .024″ = .001″.

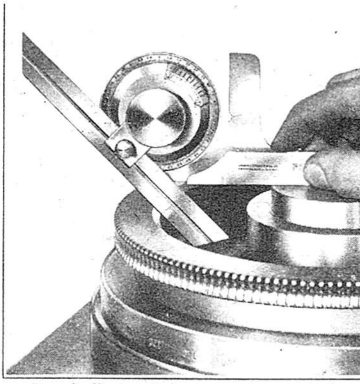
When the reading is exact, with respect to the number of fortieths of an inch, the zero on the Vernier coincides with a graduation on the scale—either inch, tenth or fortieth, as the case may be. This leaves a space between lines on the scale and the 1, 2, 3, 4, 5, 6, etc. lines on the Vernier of .001″, .002″, .003″, .004″, .005″, .006″, etc., respectively, the difference increasing .001″ at each Vernier division in numerical order until, at the 25th graduation, the lines again coincide (see upper cut).

Thus, when the 1st, 2nd or 3rd, etc. line on the Vernier coincides with a line on the scale, the zero on the Vernier has moved 1, 2 or 3, etc. thousandths of an inch past the previous fortieth graduation to bring these lines together.

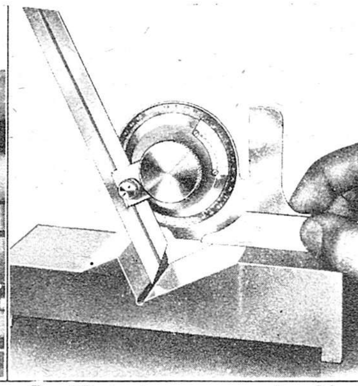
To read—Note the inches, tenths and fortieths of an inch that the zero on the Vernier has moved from the zero on the scale and to this reading add the number of thousandths indicated by the line on the Vernier that coincides with a line on the scale.

Example:—The upper cut shows the zero graduation on the Vernier coinciding with a fortieth graduation on the scale (the second fortieth beyond an even tenth graduation). This indicates that the reading is exact with respect to the fortieths of an inch. The reading therefore equals 2.000″ + .300″ + .050″ = 2.350″. The lower cut, however, shows the 18th Vernier graduation coinciding with a line on the scale. This indicates that .018″ should be added to the scale reading. The reading, then, equals 2.000″ + .300″ + .050″ + .018″ = 2.368″.

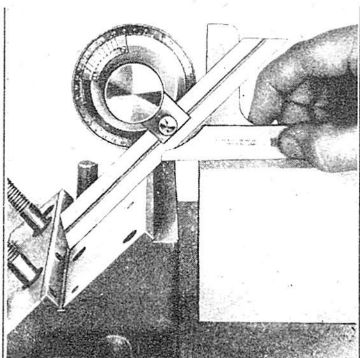
Verniers with 25 divisions are used, for English Measure, on all Brown & Sharpe Verniers with the exception of Gear Tooth Verniers No. 580, 20 to 2 diam. pitch, on which Verniers with 20 divisions are used.



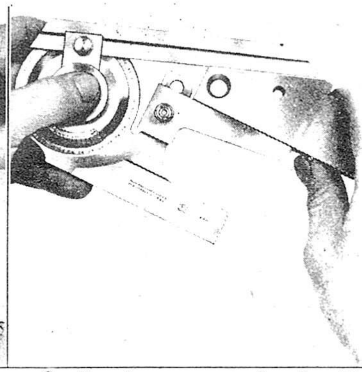
Bevel Protractor measuring angular clearance on ring gear.



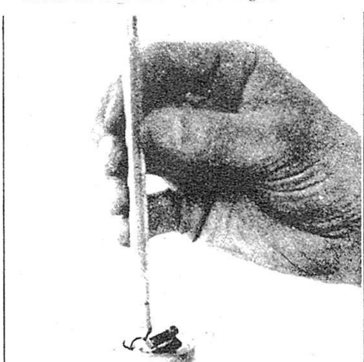
Bevel Protractor measures angle and determines its relationship to other surfaces.



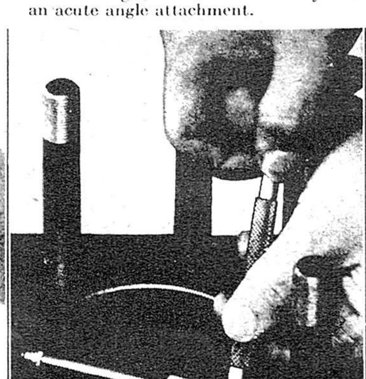
Bevel Protractor used with a test block to measure fixture angle.



Small angles are measured easily with an acute angle attachment.



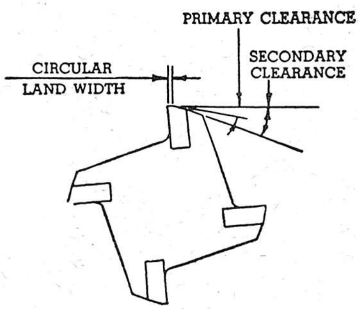
Inside Micrometer No. 263 measures holes as small as 1″.



With No. 268, the measuring point adjusts itself to the measurement.

Circular Land Widths and Clearances If it becomes necessary to regrind the diameter of a reamer, the lands must be cleared or relieved to prevent the reamer from binding in the hole. The best clearance angle and the best circular land width vary with the job, but the following table gives average figures.

Diameter of Reamer	Circular Land Width	Primary Clearance Angle
1/4"	.007"	14°
1/2"	.009"	11°
1"	.013"	9°
1 1/2"	.016"	7°
2"	.023"	7°



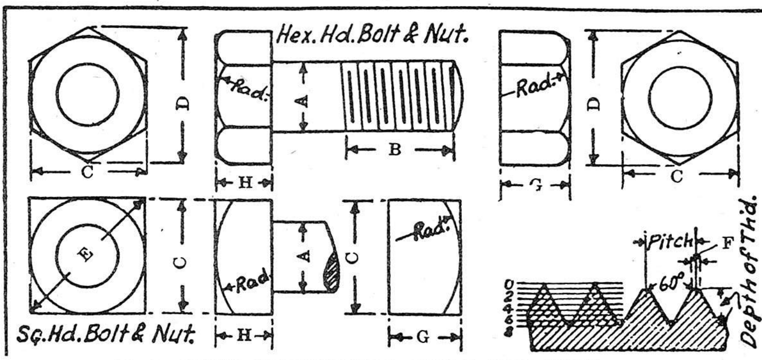
A secondary clearance is usually ground on reamers as shown above. This clearance is only to insure the back of the land being well away from the wall of the reamed hole in order to prevent rubbing.

Care of Reamers Reamers are precision tools and careful treatment of their cutting edges will pay big dividends in smooth accurate holes and long life. The use of racks, containers, or boxes will be of great help in preventing nicks along the cutting edges.

Useful Information

Included Point Angle 37°—for bottom and keel plates.
Included Point Angle 45°—for shell, side and deck plates.
Included Point Angle 53°—for oil tank and oil tight holes.
Included Point Angle 45°, 60°, and 78°—for boiler plates.

Rivet Size	Hole Size	Countersunk Face, Diameter, Inches	Size Countersink Required, Inches
5/8	11/16	1	1 1/2 or 1 3/4
3/4	13/16	1 3/16	1 1/2 or 1 3/4
7/8	15/16	1 3/8	1 3/4
1	1 1/16	1 9/16	1 3/4
1 1/8	1 3/16	1 3/4	2 or 2 1/4
1 1/4	1 5/16	1 15/16	2 or 2 1/4



U. S. STANDARD THREADS, BOLTS AND NUTS

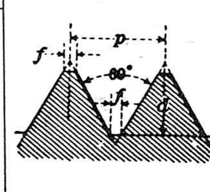
A Diameter of Bolt	B Threads per Inch	C Inside Diameter	D Outside Diameter	E Diagonal	F Width of Flat	G Thickness of Nut in Rough	H Thickness of Bolt Head	Root Diameter, Inches	Double Depth of Threads	Area of Bolt Body in Square Inches	Area at Root of Thread in Sq. In.	Width Across Flats	Width Across Corners	Thickness of Nut	Pitch Diameter in Inches	Size of Tap Drill	Tensile Strength at Stress of 6,000 lbs. per Sq. In.
1/4	20	1/2	37/64	23/32	.0062	1/4	1/4	.185	.064	0.049	0.027	7/16	1/2	3/16	.2175	13/64	160
5/16	18	19/32	11/16	27/32	.0069	5/16	19/64	.240	.072	.077	.045	17/32	39/64	1/4	.2764	1/4	270
3/8	16	11/16	51/64	31/32	.0078	3/8	11/32	.294	.081	.110	.068	5/8	23/32	5/16	.3344	5/16	410
7/16	14	25/32	29/32	1 7/64	.0089	7/16	25/64	.345	.092	.150	.093	23/32	53/64	3/8	.3911	23/64	560
1/2	13	7/8	1 1/64	1 1/4	.0096	1/2	7/16	.400	.099	.196	.126	13/16	15/16	7/16	.4459	27/64	760
9/16	12	31/32	1 1/8	1 3/8	.0104	9/16	31/64	.454	.108	.249	.162	29/32	1 1/64	1/2	.5084	15/32	1,000
5/8	11	1 1/16	1 15/64	1 1/2	.0113	5/8	17/32	.507	.118	.307	.202	1	1 5/32	9/16	.5660	17/32	1,210
3/4	10	1 1/4	1 7/16	1 25/32	.0125	3/4	5/8	.620	.129	.442	.302	1 3/16	1 21/64	11/16	.6851	41/64	1,810
7/8	9	1 7/8	1 21/32	2 1/32	.0139	7/8	23/32	.731	.144	.601	.420	1 3/8	1 19/32	13/16	.8029	3/4	2,520
1	8	1 5/8	1 7/8	2 19/64	.0156	1	13/16	.838	.162	.785	.550	1 9/16	1 13/16	15/16	.9188	53/64	3,300
1 1/8	7	1 13/16	2 3/32	2 9/16	.0178	1 1/8	29/32	.939	.185	.994	.694	1 3/4	2 1/64	1 1/16	1.0322	31/32	4,160
1 1/4	7	2	2 5/16	2 53/64	.0178	1 1/4	1	1.064	.186	1.227	.891	1 15/16	2 15/64	1 3/16	1.1572	1 3/32	5,350
1 3/8	6	2 3/16	2 17/32	3 3/32	.0208	1 3/8	1 3/32	1.158	.215	1.485	1.057	2 1/8	2 29/64	1 5/16	1.2668	1 7/32	6,340
1 1/2	6	2 3/8	2 3/4	3 23/64	.0208	1 1/2	1 3/16	1.283	.216	1.765	1.295	2 5/16	2 43/64	1 7/16	1.3918	1 11/32	7,770
1 5/8	5 1/2	2 9/16	2 31/32	3 5/8	.0227	1 5/8	1 9/32	1.389	.236	2.074	1.515	2 1/2	2 57/64	1 9/16	1.5070	1 27/64	9,090
1 3/4	5	2 3/4	3 3/16	3 57/64	.0250	1 3/4	1 3/8	1.490	.259	2.405	1.746	2 11/16	3 7/64	1 11/16	1.6201	1 17/32	10,470
1 7/8	5	2 15/16	3 25/64	4 5/32	.0250	1 7/8	1 15/32	1.615	.260	2.761	2.051	2 7/8	3 21/64	1 13/16	1.7451	1 21/32	12,300
2	4 1/2	3 1/8	3 39/64	4 27/64	.0278	2	1 9/16	1.711	.288	3.142	2.302	3 1/16	3 17/32	1 15/16	1.8557	1 49/64	13,800

INTERNATIONAL STANDARD THREAD

(Metric System)

Formula
p = pitch
d = depth = $p \times .64952$
f = flat = $\frac{p}{8}$

Diameter m/m	Pitch m/m	Diameter m/m	Pitch m/m	Diameter m/m	Pitch m/m
6	1.0	20	2.5	48	5.0
7	1.0	22	2.5	52	5.0
8	1.25	24	3.0	56	5.5
9	1.25	27	3.0	60	5.5
10	1.5	30	3.5	64	6.0
11	1.5	33	3.5	68	6.0
12	1.75	36	4.0	72	6.5
14	2.0	39	4.0	76	6.5
16	2.0	42	4.5	80	7.0
18	2.5	45	4.5		



SHIELDS TAP DRILL TABLE

Tap Drill List for V-Standard Thread

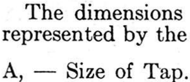
Size of Tap	Threads per Inch	Tap Drill for Full Thread	Tap Drill for Shop Practice	Size of Tap	Threads per Inch	Tap Drill for Full Thread	Tap Drill for Shop Practice	Size of Tap	Threads per Inch	Tap Drill for Full Thread	Tap Drill for Shop Practice
A	B	C	D	A	B	C	D	A	B	C	D
3/32	48	50	47	5/16	16	1	1/4	5/8	12	33/64	35/64
3/32	56	49	46	5/16	18	15/64	1/4	21/32	10	33/64	17/32
3/32	60	48	45	5/16	20	E 1/4	17/64	21/32	11	17/32	9/16
7/64	32	50	45	5/16	24	F 17/64	17/64	21/32	12	35/64	37/64
7/64	36	49	44	11/32	16	F 17/64	9/32	3/4	10	39/64	5/8
7/64	40	47	43	11/32	18	17/64	9/32	3/4	11	5/8	41/64
1/8	32	44	40	3/8	14	9/32	19/64	3/4	12	41/64	21/32
1/8	36	43	38	3/8	16	L 19/64	5/16	25/32	10	41/64	21/32
1/8	40	42	37	3/8	18	19/64	5/16	25/32	11	21/32	11/16
1/8	44	37	36	3/8	24	P 21/64	11/32	25/32	12	43/64	45/64
9/64	30	41	35	13/32	14	N 19/64	21/32	13/16	10	43/64	45/64
9/64	32	40	32	13/32	16	P 21/64	11/32	27/32	10	45/64	47/64
9/64	36	37	35	13/32	18	21/64	11/32	7/8	9	23/32	3/4
5/32	30	33	31	7/16	14	R 11/32	25/64	7/8	10	47/64	49/64
5/32	32	32	30	7/16	16	S 11/32	25/64	29/32	9	3/4	49/64
5/32	36	31	29	7/16	27	3/8	25/64	29/32	10	49/64	25/32
5/32	40	30	29	15/32	14	3/8	25/64	15/16	9	49/64	53/64
3/16	24	29	27	15/32	16	W 25/64	13/32	31/32	9	13/16	53/64
3/16	30	27	23	1/2	12	25/64	13/32	1	8	27/32	7/8
3/16	32	27	20	1/2	13	X 25/64	13/32	1 1/32	8	55/64	57/64
7/32	24	20	17	1/2	14	13/32	13/32	1 1/16	8	57/64	15/16
7/32	28	16	15	17/32	12	27/64	7/16	1 3/32	8	59/64	61/64
7/32	30	16	15	17/32	13	27/64	7/16	1 1/8	7	59/64	63/64
7/32	32	15	15	17/32	14	7/16	29/64	1 1/8	8	61/64	1
1/4	18	17	3/16	9/16	12	29/64	15/32	1 5/32	7	61/64	1
1/4	20	14	3/16	9/16	14	15/32	1/2	1 5/32	8	63/64	1 1/64
1/4	24	9	6	19/32	12	31/64	1/2	1 3/16	7	63/64	1 3/64
1/4	27	7	6	19/32	14	1/2	33/64	1 1/4	7	1 3/64	1 7/64
9/32	18	13/64	7/32	5/8	10	31/64	33/64	1 3/8	6	1 1/8	1 7/32
9/32	20	3	2	5/8	11	1/2	17/32	1 1/2	6	1 17/64	1 11/32

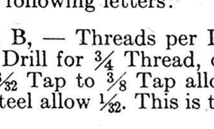
The dimensions for taps and tap drills, given in the Shields Tap Drill Table, are represented by the following letters:

A, — Size of Tap. B, — Threads per Inch. C, — Size of Tap Drill for Full Thread. D, — Size of Tap Drill for 3/4 Thread, or Shop Practice. Few Suggestions for Drilling Tap Holes. From 3/32 Tap to 3/8 Tap allow 1/128 or .0078. From 3/8 Tap up, allow 1/64. For C. I. and for Steel allow 1/32. This is to be added on letter C, the Full Thread.

SHARP "V" THREAD (THEORETICAL)

"MODIFIED" V THREAD





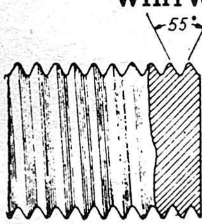
Formula $\begin{cases} p = \text{pitch} = \dfrac{1}{\text{No. threads per inch}} \\ d = \text{depth} = p \times .86603 \end{cases}$

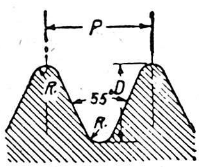
SIZES OF TAP DRILLS

For Machine Screw Taps A. S. M. E. Standard

Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.
0-80	56	5-44	37	10-24	25	20-16	G
1-56	54	6-32	36	10-28	23	20-18	17/64
1-64	53	6-36	34	10-30	22	20-20	I
1-72	53	6-40	33	10-32	21	22-16	9/32
2-56	50	7-30	31	12-24	16	22-18	L
2-64	50	7-32	31	12-28	14	24-16	5/16
3-48	47	7-36	1/8	12-32	13	24-18	O
3-56	45	8-30	30	14-20	10	26-14	21/64
4-32	45	8-32	29	14-24	7	26-16	R
4-36	44	8-36	29	16-18	3	28-14	T
4-40	43	8-40	28	16-20	7/32	28-16	23/64
4-48	42	9-24	29	16-22	2	30-14	V
5-36	40	9-30	27	18-18	B	30-16	25/64
5-40	38	9-32	26	18-20	D	....	....

WHITWORTH STANDARD BOLTS AND SCREWS





Whitworth Screw Thread Form

WHITWORTH THREAD FORMULA

$$P = \text{Pitch} = \frac{1}{\text{No. Th'ds. Per In.}}$$

$$D = \text{Depth} = P. \times .6403$$

$$R. = \text{Radius} = .1373\ P.$$

Full Diam.	Decimal Equiv. Outside Diam.	No. of Th'ds. Per Inch	Pitch Inches	Stand. Depth of Thread	Effective Diam. (pitch diam.)	Core Diam.	Cross Sectional Area at Bottom of Th'ds.	*DRILL SIZES Nearest Commercial Drill Size to Produce 75% Depth of Thread (Actual) Inch Decim.	(Nearest) Com. Desig.
1/4	.25	20	.0500	.03201	.2179	.1856	.0272	.202	13/64 in.
5/16	.3125	18	.0556	.03557	.2769	.2413	.0458	.2592	F
3/8	.375	16	.0625	.04002	.3349	.2949	.0683	.3150	O
7/16	.4375	14	.0714	.04573	.3917	.3460	.0940	.3689	U
1/2	.5	12	.0833	.05336	.4466	.3932	.1215	.4200	27/64 in.
9/16	.5625	12	.0833	.05336	.5091	.4557	.1632	.4825	31/64 in.
5/8	.625	11	.0909	.05821	.5667	.5085	.2032	.5377	35/64 in.
11/16	.6875	11	.0909	.05821	.6292	.5710	.2562	.6002	29/64 in.
3/4	.75	10	.1000	.06403	.6859	.6219	.3038	.6539	21/32 in.
13/16	.8125	10	.1000	.06403	.7484	.6844	.3679	.7164	23/32 in.
7/8	.875	9	.1111	.07114	.8038	.7327	.4216	.7683	49/64 in.
1	1.000	8	.1250	.08004	.9199	.8399	.5540	.8799	7/8 in.
1 1/8	1.125	7	.1429	.09147	1.0335	.9421	.6969	.9877	1 in.
1 1/4	1.25	7	.1429	.09147	1.1585	1.0671	.8942	1.1127	1 7/64 in.
1 3/8	1.375	6	.1667	.10672	1.2682	1.1615	1.0597	1.2149	1 7/32 in.
1 1/2	1.5	6	.1667	.10672	1.3932	1.2865	1.3001	1.3399	1 11/32 in.
1 5/8	1.625	5	.2000	.12806	1.4969	1.3688	1.4718	1.4329	1 7/32 in.
1 3/4	1.75	5	.2000	.12806	1.6219	1.4938	1.7528	1.5579	1 9/16 in.
2	2.000	4 1/2	.2222	.14228	1.8577	1.7154	2.3111	1.7865	1 25/32 in.

MACHINE AND WOOD SCREW GAUGE

Number of Screw Gauge	Size of Number in Decimals	Number of Screw Gauge	Size of Number in Decimals
000	.03152	25	.38684
00	.04468	26	.40000
0	.05784	27	.41316
1	.07100	28	.42632
2	.08416	29	.43948
3	.09732	30	.45264
4	.11048	31	.46580
5	.12364	32	.47896
6	.13680	33	.49212
7	.14996	34	.50528
8	.16312	35	.51844
9	.17628	36	.53160
10	.18944	37	.54476
11	.20260	38	.55792
12	.21576	39	.57108
13	.22892	40	.58424
14	.24208	41	.59740
15	.25524	42	.61056
16	.26840	43	.62372
17	.28156	44	.63688
18	.29472	45	.65004
19	.30788	46	.66320
20	.32104	47	.67636
21	.33420	48	.68952
22	.34736	49	.70268
23	.36052	50	.71584
24	.37368		

The difference between consecutive sizes is .01316 inch.

FOR SETTING TOOLS TO CUT SQUARE THREADS

By Edw. Greasse 3945 Blaine Ave., St. Louis, Mo.

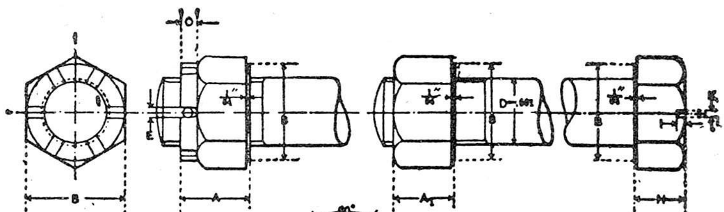
Threads Per Inch	Width of Tool for Single Thread	Width of Tool for Double Thread	Width of Tool for Triple Thread
1	.500	.250	.166
2	.250	.125	.083
3	.166	.083	.055
4	.125	.062	.042
5	.100	.050	.033
6	.083	.042	.028
7	.071	.035	.073
8	.062	.031	.021
9	.055	27½	18½
10	.050	25	16⅔
11	.045	22½	15
12	.041½	21	14

HEXAGON HEAD SCREWS, CASTLE AND PLAIN NUTS

S. A. E. Standard

It is assumed that where screws are to be used in soft material, such as castiron, brass, bronze or aluminum, the United States standard pitches will be used.

DIMENSIONS



B = REFERS TO ALL NUTS AND SCREW HEADS
D = DIAMETER OF SCREW
d = DIAMETER OF COTTER PIN

D x 1.5 = LENGTH OF THREADED PORTION
P = PITCH OF THREAD
F = FLAT TOP

D	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
P	2S	24	24	20	20	18	18	16	16	14	14	12	12	12	12
A	9/32	21/64	13/32	29/64	9/16	39/64	23/32	49/64	13/16	29/32	1	1 5/32	1 1/4	1 13/32	1 1/2
A^1	7/32	17/64	21/64	3/8	7/16	31/64	35/64	19/32	21/32	40/64	7/8	63/64	1 3/32	1 13/64	1 5/16
B	7/16	1/2	9/16	5/8	3/4	7/8	15/16	1	1 1/16	1 1/4	1 7/16	1 5/8	1 13/16	2	2 3/16
C	3/32	3/32	1/8	1/8	3/16	3/16	1/4	1/4	1/4	1/4	1/4	5/16	5/16	3/8	3/8
E	5/64	5/64	1/8	1/8	1/8	5/32	5/32	5/32	5/32	5/32	5/32	7/32	7/32	1/4	1/4
H	3/16	15/64	9/32	21/64	3/8	27/64	15/32	33/64	9/16	21/32	3/4	27/32	15/16	1 1/32	1 1/8
I	3/32	7/64	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	7/32	7/32	1/4	1/4
K	1/16	1/16	3/32	3/32	3/32	3/32	3/32	3/32	3/32	3/32	3/32	5/32	5/32	3/16	3/16
d	1/16	1/16	3/32	3/32	3/32	1/8	1/8	1/8	1/8	1/8	1/8	11/64	11/64	13/64	13/64

Dimensions. All dimensions in inches.

Finish. All heads and nuts to be semi-finish.

Material. For all screws and nuts — steel.

Screws are to be left soft. Screw heads are to be left soft. The plain nuts are to be soft. The Castle nuts are to be case-hardened.

HOW TO DRILL GLASS

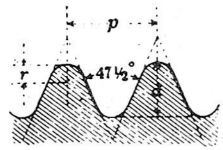
Take an old three-cornered file — one that is worn out will do — break it off and sharpen to a point like a drill and place in a carpenter's brace or vise. Have the glass fastened on a good solid table so there will be no danger of its breaking. Wet the glass at the point where the hole is to be made with the following solution:

Ammonia	6 1/2 drachms
Ether	3 1/2 drachms
Turpentine	1 ounce

Keep the drill wet with the above solution and bore the hole part way from each side of the glass. Another solution is to dissolve a piece of gum camphor the size of a walnut in one ounce of turpentine.

Another method is to use a steel drill hardened, but not drawn. Saturate spirits of turpentine with camphor and wet the drill. The drill should be ground with a long point and plenty of clearance. Run the drill fast and with a light feed. In this manner glass can be drilled with holes, up to 3/16-inch diameter, nearly as rapidly as cast steel.

BRITISH ASSOCIATION STANDARD THREAD



Formula $\begin{cases} p = \text{pitch} \\ d = \text{depth} = p \times .6 \\ r = \text{radius} = \dfrac{2 \times p}{11} \end{cases}$

Number	Diameter m/m	Pitch m/m	Number	Diameter m/m	Pitch m/m
0	6.0	1.00	7	2.5	0.48
1	5.3	0.90	8	2.2	0.43
2	4.7	0.81	9	1.9	0.39
3	4.1	0.73	10	1.7	0.35
4	3.64	0.66	12	1.3	0.28
5	3.2	0.59	14	1.0	0.23
6	2.8	0.53	16	.79	0.19

STOVE BOLT TAPS
Cut Thread — Manufacturers Standard
Thread Limits

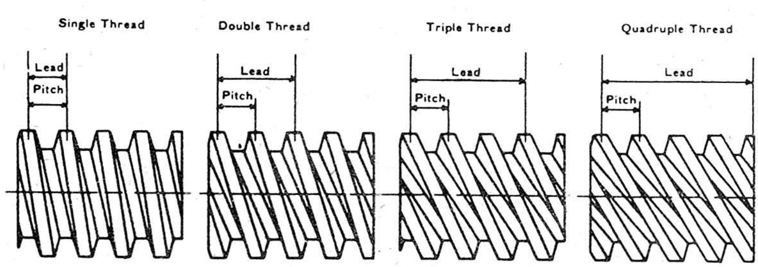
Size	Threads per Inch S.B.	Major Diameter			Pitch Diameter		
		Basic	Minimum	Maximum	Basic	Minimum	Maximum
1/8	32	.1250	.1280	.1310	.1080	.1110	.1130
5/32	28	.1630	.1660	.1690	.1440	.1470	.1490
3/16	24	.1950	.1980	.2010	.1730	.1760	.1780
7/32	22	.2220	.2255	.2285	.1980	.2015	.2035
1/4	18	.2500	.2525	.2555	.2240	.2275	.2295
5/16	18	.3125	.3150	.3180	.2764	.2779	.2804
3/8	16	.3750	.3780	.3810	.3344	.3359	.3384
7/16	14	.4375	.4400	.4440	.3911	.3926	.3956
1/2	13	.5000	.5030	.5070	.4500	.4515	.4545

Lead Tolerance

A maximum lead error of plus or minus .003" in one inch of thread is permitted.

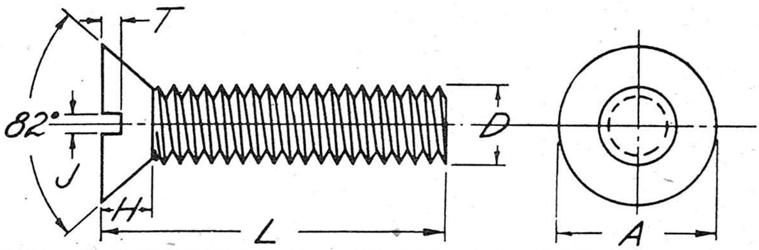
Multiple Threads

The following drawing illustrates the relation of "pitch" and "lead" of multiple threads. Both these dimensions should always be given when ordering.



Relation of Lead and Pitch of Multiple Threads

FLAT HEAD MACHINE SCREWS



Nominal Size	D	*A		H		J		T	
	Basic Major Diameter	Head Diameter		Height of Head		Width of Slot		Depth of Slot	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2	.086	.172	.156	.051	.040	.036	.024	.023	.015
3	.099	.199	.181	.059	.048	.038	.026	.027	.017
4	.112	.225	.207	.067	.055	.040	.028	.030	.020
5	.125	.252	.232	.075	.062	.043	.031	.034	.022
6	.138	.279	.257	.083	.069	.045	.033	.038	.024
8	.164	.332	.308	.100	.084	.050	.037	.045	.029
10	.190	.385	.359	.116	.098	.055	.041	.053	.034
12	.216	.438	.410	.132	.112	.059	.045	.060	.039
1/4	.250	.507	.477	.153	.131	.066	.051	.070	.046
5/16	.3125	.636	.600	.192	.166	.077	.061	.088	.058
3/8	.375	.762	.722	.230	.200	.088	.072	.106	.070

FORMULAS

HEAD DIAMETER:
Maximum $A = 2.040\ D - 0.003$
Minimum $A = 1.960\ D - 0.013$

HEIGHT OF HEAD:
Maximum $H = 0.619\ D - 0.002$
Minimum $H = 0.552\ D - 0.007$

WIDTH OF SLOT:
Maximum $J = 0.182\ D + 0.020$
Minimum $J = 0.164\ D + 0.010$

DEPTH OF SLOT:
Maximum $T = 0.288\ D - 0.002$
Minimum $T = 0.192\ D - 0.002$

COUNTERSINK ANGLE:
Maximum 82 Deg.
Minimum 80 Deg.

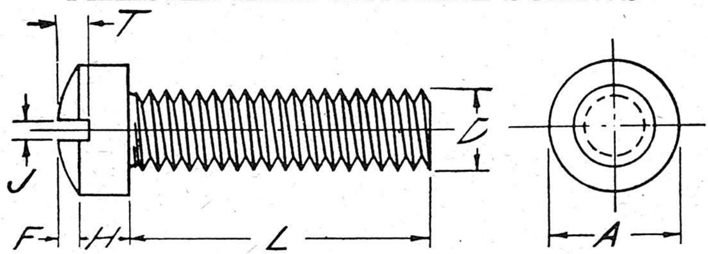
Machine screws up to and including 2" length are threaded to the head. Screws longer than 2" are threaded 2".

*Flat heads cannot be measured on head diameter. Use form gauges.

(S.A.E. Standard)

Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.
1/4-28	3	1/2-20	29/64	3/4-16	11/16	1 1/4-12	1 11/64
5/16-24	I	9/16-18	33/64	7/8-14	13/16	1 3/8-12	1 19/64
3/8-24	Q	5/8-18	37/64	1 -14	15/16	1 1/2-12	1 27/64
7/16-20	25/64	11/16-16	5/8	1 1/8-12	1 3/64	....	....

FILLISTER HEAD MACHINE SCREWS



Nominal Size	D	A		H		J		T		F		F + H	
	Basic Major Dia.	Head Diameter		Height of Head		Width of Slot		Depth of Slot		Height of Oval		Total Height of Head	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min	Max.	Min.	Max.	Min.
2	.086	.140	.124	.055	.045	.036	.024	.037	.021	.028	.018	.073	.063
3	.099	.161	.145	.063	.052	.038	.026	.043	.026	.032	.021	.084	.073
4	.112	.183	.166	.072	.060	.040	.028	.048	.031	.035	.024	.096	.084
5	.125	.205	.187	.081	.068	.043	.031	.054	.036	.039	.027	.107	.095
6	.138	.226	.208	.089	.076	.045	.033	.060	.041	.043	.029	.118	.105
8	.164	.270	.250	.106	.091	.050	.037	.071	.050	.050	.035	.141	.126
10	.190	.313	.292	.123	.107	.055	.041	.083	.060	.057	.041	.164	.148
12	.216	.357	.334	.141	.123	.059	.045	.094	.070	.064	.047	.187	.169
¼	.250	.414	.389	.163	.143	.066	.051	.109	.083	.074	.054	.217	.197
5/16	.3125	.519	.490	.205	.181	.077	.061	.137	.106	.092	.068	.272	.249
⅜	.375	.622	.590	.246	.218	.088	.072	.164	.129	.109	.082	.327	.300

FORMULAS

HEAD DIAMETER:
Maximum A = 1.670 D − 0.004
Minimum A = 1.610 D − 0.014

HEIGHT OF HEAD (SIDE):
Maximum H = 0.660 D − 0.002
Minimum H = 0.600 D − 0.007

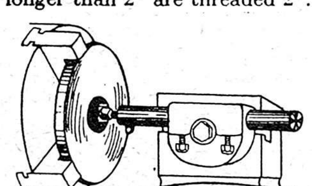
WIDTH OF SLOT:
Maximum J = 0.182 D + 0.020
Minimum J = 0.164 D + 0.010

DEPTH OF SLOT:
Maximum T = 0.440 D − 0.001
Minimum T = 0.374 D − 0.011

HEIGHT OF HEAD:
Maximum F = 0.280 D + 0.004
Minimum F = 0.220 D − 0.001

TOTAL HEIGHT OF HEAD:
Maximum F + H = Maximum F + Minimum H = 0.88 D − 0.003
Minimum F + H = Minimum F + Minimum H = 0.82 D − 0.008

Machine screws up to and including 2″ length are threaded to the head. Screws longer than 2″ are threaded 2″.

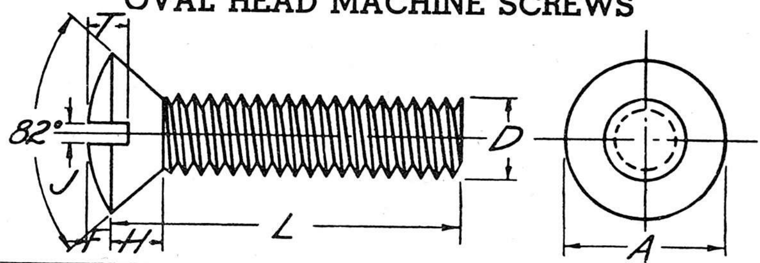


To produce absolutely straight and true holes, drill used to rough out stock should leave hole about $\frac{3}{64}''$ to $\frac{1}{16}''$ small.

Use boring bar mounted in tool post (as illustrated), and bore hole until about eight to ten thousandths stock are left.

To act as true guide for reamer, bore hole at outer end—or end reamer enters for ⅛″—to about three thousandths small.

OVAL HEAD MACHINE SCREWS



Nominal Size	D	*A		H		J		T		F		F + H	
	Basic Major Dia.	Head Diameter		Height of Head		Width of Slot		Depth of Slot		Height of Oval		Total Height of Head	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2	.086	.172	.156	.051	.040	.036	.024	.045	.037	.029	.022	.080	.063
3	.099	.199	.181	.059	.048	.038	.026	.052	.043	.033	.026	.092	.073
4	.112	.225	.207	.067	.055	.040	.028	.059	.049	.037	.029	.104	.084
5	.125	.252	.232	.075	.062	.043	.031	.067	.055	.041	.033	.116	.095
6	.138	.279	.257	.083	.069	.045	.033	.074	.060	.045	.036	.128	.105
8	.164	.332	.308	.100	.084	.050	.037	.088	.072	.053	.043	.152	.126
10	.190	.385	.359	.116	.098	.055	.041	.103	.084	.061	.050	.176	.148
12	.216	.438	.410	.132	.112	.059	.045	.117	.096	.069	.057	.200	.169
¼	.250	.507	.477	.153	.131	.066	.051	.136	.112	.079	.066	.232	.197
5/16	.3125	.636	.600	.192	.166	.077	.061	.171	.141	.098	.083	.290	.249
⅜	.375	.762	.722	.230	.200	.088	.072	.206	.170	.117	.100	.347	.300

FORMULAS

HEAD DIAMETER:
Maximum $A = 2.04\ D - 0.003$
Minimum $A = 1.96\ D - 0.013$

HEIGHT OF HEAD:
Maximum $H = 0.619\ D - 0.002$
Minimum $H = 0.552\ D - 0.007$

WIDTH OF SLOT:
Maximum $J = 0.182\ D + 0.020$
Minimum $J = 0.164\ D + 0.010$

DEPTH OF SLOT:
Maximum $T = 0.556\ D - 0.003$
Minimum $T = 0.460\ D - 0.003$

HEIGHT OF OVAL:
Maximum $F = 0.304\ D + 0.003$
Minimum $F = 0.268\ D - 0.001$

COUNTERSINK ANGLE:
Maximum 82 Deg.
Minimum 80 Deg.

TOTAL HEIGHT OF HEAD:
Maximum $(F+H)$ = Maximum F + Maximum $H = 0.923\ D + 0.001$
Minimum $(F+H)$ = Minimum F + Minimum $H = 0.820\ D - 0.008$

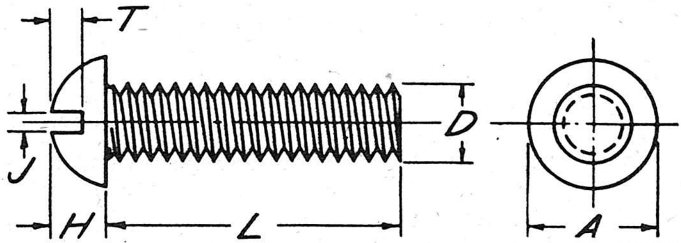
Machine screws up to and including 2″ length are threaded to the head. Screws longer than 2″ are threaded 2″.

*Oval heads cannot be measured on head diameter. Use form gauges.

Cut Thread—For Grease Cup Fittings

Nominal Size Inches	Number of Threads to Inch Amer. Std.	Major Diameter			Pitch Diameter		
		Basic	Minimum	Maximum	Basic	Minimum	Maximum
⅛	27	.4044	.3975	.3995	.3748	.3680	.3700
¼	18	.5343	.5255	.5275	.4899	.4810	.4830
⅜	18	.6714	.6625	.6645	.6270	.6180	.6200
½	14	.8355	.8245	.8270	.7784	.7670	.7695
¾	14	1.0460	1.0345	1.0370	.9889	.9775	.9800
1	11½	1.3082	1.2945	1.2970	1.2386	1.2245	1.2275

ROUND HEAD MACHINE SCREWS



Nominal Size	D	A		H		J		T	
	Basic Major Diameter	Head Diameter		Height of Head		Width of Slot		Depth of Slot	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2	.086	.162	.146	.070	.059	.036	.024	.048	.036
3	.099	.187	.169	.078	.067	.038	.026	.053	.040
4	.112	.211	.193	.086	.075	.040	.028	.058	.043
5	.125	.236	.217	.095	.083	.043	.031	.062	.047
6	.138	.260	.240	.103	.091	.045	.033	.067	.050
8	.164	.309	.287	.119	.107	.050	.037	.076	.057
10	.190	.359	.334	.136	.124	.055	.041	.086	.064
12	.216	.408	.382	.152	.140	.059	.045	.095	.071
1/4	.250	.472	.443	.174	.161	.066	.051	.108	.080
5/16	.3125	.591	.557	.214	.200	.077	.061	.130	.097
3/8	.375	.708	.670	.254	.239	.088	.072	.153	.114

FORMULAS

Head Diameter:
Maximum $A = 1.887\ D.$
Minimum $A = 1.813\ D - 0.010$

Height of Head:
Maximum $H = 0.636\ D + 0.015$
Minimum $H = 0.624\ D + 0.005$

Width of Slot:
Maximum $J = 0.182\ D + 0.020$
Minimum $J = 0.164\ D + 0.010$

Depth of Slot:
Maximum $T = 0.362\ D + 0.017$
Minimum $T = 0.268\ D + 0.013$

Machine screws up to and including 2" length are threaded to the head. Screws longer than 2" are threaded 2"

SIZES OF WIRES FOR USE WITH VARIOUS PITCH THREADS.

PITCH	WIRE
4 to 6	.150"
7 to 9	.090"
10 to 12	.070"
13 to 16	.050"
18 to 24	.035"
26 to 30	.030"
32 to 40	.025"
42 to 50	.018"
52 to 60	.015"

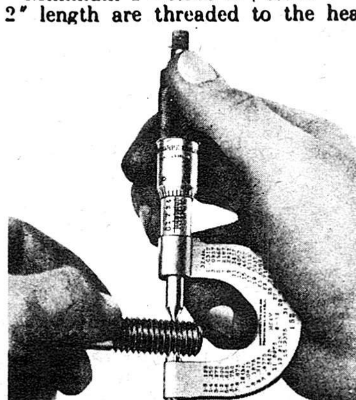
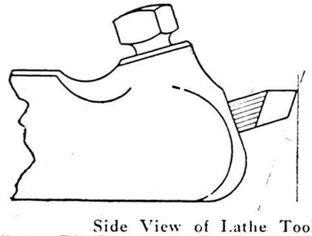


Chart of Wrench and Socket Openings and Sizes of Bolts and Nuts they fit

Wrench Opening	American Standard Reg. Bolts	American Standard Reg. Nuts, Size Bolts	Amer. Std. Heavy Nuts (U.S.S.), Size Bolts	Amer. Std. Light Nuts (S.A.E.), Jam Nuts, Castle Nuts and Slotted Nuts, Size Bolts	Cap Screws	Set Screws	Machine Screw Nuts and Stove Bolt Nuts	Wrench Opening
5/32							No. 0 & No. 1	5/32
3/16							No. 2 & No. 3	3/16
1/4						1/4	No. 4	1/4
5/16						5/16	No. 5 & No. 6	5/16
11/32							No. 8	11/32
3/8	1/4					3/8	No. 10	3/8
7/16		1/4		1/4	1/4	7/16	No. 12 & No. 14	7/16
1/2	5/16		1/4	5/16	5/16	1/2		1/2
9/16	3/8	5/16		3/8	3/8	9/16	5/16	9/16
19/32			5/16					19/32
5/8	7/16	3/8		7/16	7/16	5/8	3/8	5/8
11/16			3/8					11/16
3/4	1/2	7/16		1/2	1/2	3/4		3/4
25/32			7/16					25/32
13/16		1/2			9/16			13/16
7/8	9/16	9/16	1/2	9/16	5/8	7/8		7/8
15/16	5/8		9/16	5/8				15/16
1		5/8			3/4	1		1
1 1/16			5/8	3/4				1 1/16
1 1/8	3/4	3/4			7/8	1 1/8		1 1/8
1 1/4			3/4	7/8		1 1/4		1 1/4
1 5/16	7/8	7/8			1			1 5/16
1 3/8						1 3/8		1 3/8
1 7/16			7/8	1				1 7/16
1 1/2	1	1			1 1/8	1 1/2		1 1/2
1 5/8			1	1 1/8				1 5/8
1 11/16	1 1/8	1 1/8			1 1/4			1 11/16
1 13/16			1 1/8	1 1/4				1 13/16
1 7/8	1 1/4	1 1/4						1 7/8
2			1 1/4	1 3/8				2
2 1/16	1 3/8	1 3/8						2 1/16
2 3/16			1 3/8	1 1/2				2 3/16
2 1/4	1 1/2	1 1/2						2 1/4
2 3/8			1 1/2					2 3/8
2 7/16	1 5/8	1 5/8						2 7/16
2 9/16			1 5/8					2 9/16
2 5/8	1 3/4	1 3/4						2 5/8
2 3/4			1 3/4					2 3/4
2 13/16	1 7/8	1 7/8						2 13/16
2 15/16			1 7/8					2 15/16
3	2	2						3
3 1/8			2					3 1/8
3 3/8	2 1/4	2 1/4						
3 1/2			2 1/4					
3 3/4	2 1/2	2 1/2						
3 7/8			2 1/2					
4 1/8	2 3/4	2 3/4						
4 1/4			2 3/4					
4 1/2	3	3						
4 5/8			3					
5			3 1/4					
5 3/8			3 1/2					
5 3/4			3 3/4					
6 1/8			4					



Side View of Lathe Tool Cutter Bit Ground for Cutting Screw Threads

Front Clearance

There must be sufficient front clearance on the cutter bit to permit it to cut freely. Usually the front clearance is sufficient to prevent the tool from dragging in the helix angle of the thread so that except for very coarse pitches the helix angle may be ignored.

Double Depth of Threads

Threads per Inch	Double Depth U. S. Standard Thread	Double Depth Sharp V Thread	Double Depth Whitworth Standard Thread	Threads per Inch	Double Depth U. S. Standard Thread	Double Depth Sharp V Thread	Double Depth Whitworth Standard Thread
2¼	0.5774	0.7698	0.5692	30	0.0433	0.0577	0.0427
2⅜	0.5470	0.7293	0.5392	32	0.0406	0.0541	0.0400
2½	0.5196	0.6928	0.5123	34	0.0382	0.0509	0.0377
2⅝	0.4949	0.6598	0.4879	36	0.0361	0.0481	0.0356
2¾	0.4724	0.6298	0.4657	38	0.0342	0.0456	0.0337
2⅞	0.4518	0.6025	0.4454	40	0.0325	0.0433	0.0320
3	0.4330	0.5774	0.4269	42	0.0309	0.0412	0.0305
3¼	0.3997	0.5329	0.3940	44	0.0295	0.0394	0.0291
3½	0.3712	0.4949	0.3659	46	0.0282	0.0377	0.0278
4	0.3248	0.4330	0.3202	48	0.0271	0.0361	0.0267
4½	0.2887	0.3849	0.2846	50	0.0260	0.0346	0.0256
5	0.2598	0.3464	0.2561	52	0.0250	0.0333	0.0246
5½	0.2362	0.3149	0.2328	54	0.0241	0.0321	0.0237
6	0.2165	0.2887	0.2134	56	0.0232	0.0309	0.0229
7	0.1856	0.2474	0.1830	58	0.0224	0.0299	0.0221
8	0.1624	0.2165	0.1601	60	0.0217	0.0289	0.0213
9	0.1443	0.1925	0.1423	62	0.0209	0.0279	0.0206
10	0.1299	0.1732	0.1281	64	0.0203	0.0271	0.0200
11	0.1181	0.1575	0.1164	66	0.0197	0.0263	0.0194
12	0.1083	0.1443	0.1067	68	0.0191	0.0255	0.0188
13	0.0999	0.1332	0.0985	70	0.0185	0.0248	0.0183
14	0.0928	0.1237	0.0915	72	0.0180	0.0241	0.0178
15	0.0866	0.1155	0.0854	74	0.0175	0.0234	0.0173
16	0.0812	0.1083	0.0800	76	0.0171	0.0228	0.0167
18	0.0722	0.0962	0.0711	78	0.0167	0.0222	0.0164
20	0.0650	0.0866	0.0640	80	0.0162	0.0217	0.0160
22	0.0590	0.0787	0.0582	82	0.0158	0.0211	0.0156
24	0.0541	0.0722	0.0534	84	0.0155	0.0206	0.0152
26	0.0500	0.0666	0.0493	86	0.0151	0.0201	0.0148
27	0.0481	0.0642	0.0474	88	0.0148	0.0196	0.0145
28	0.0464	0.0619	0.0457	90	0.0144	0.0192	0.0142

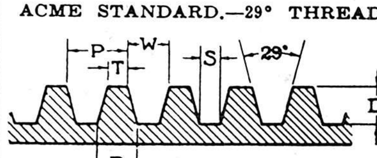
Double Depth for U. S. Standard Thread............... $= \frac{1.299}{N}$

Double Depth for Sharp V Thread................... $= \frac{1.732}{N}$

Double Depth for Whitworth Standard Thread.......... $= \frac{1.281}{N}$

	D	T	S	W	R
No. of Threads Per Inch.	**Depth of Thread.**	**Thickness at Top of Thread.**	**Width Space at Bottom of Thread.**	**Space at Top of Thread.**	**Thickness at Root of Thread.**
1	.5100	.3707	.3655	.6293	.6345
1⅓	.3850	.2780	.2728	.4720	.4772
2	.2600	.1853	.1801	.3147	.3199
3	.1767	.1235	.1183	.2098	.2150
4	.1350	.0927	.0875	.1573	.1625
5	.1100	.0741	.0689	.1259	.1311
6	.0933	.0618	.0566	.1049	.1101
7	.0814	.0529	.0478	.0899	.0951
8	.0725	.0463	.0411	.0787	.0839
9	.0655	.0412	.0361	.0699	.0751
10	.0600	.0371	.0319	.0629	.0681

ACME STANDARD.—29° THREAD



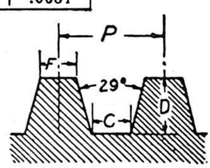
FORMULA

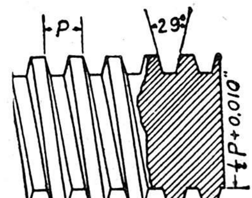
$P = \text{Pitch} = \frac{1}{\text{No Th'ds. Per In.}}$

$D = \text{Depth} = \frac{1}{2}\,P. + .010\ \text{In.}$

$F = \text{Flat} = .3707\ P.$

$C = \text{Flat} = .3707\ P. - .0052\ \text{In.}$

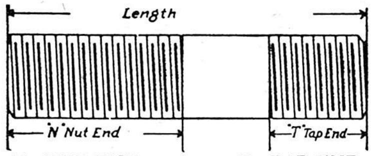




Milled Steel Stud Dimensions

American Standard Coarse Thread

(FORMERLY U.S.S.)



N = NUT END T = TAP END

Diameter	3/8		7/16		1/2		5/8		3/4		7/8		1	
Threads per Inch	16		14		13		11		10		9		8	
	N	T	N	T	N	T	N	T	N	T	N	T	N	T
Length														
1	1/2	1/2	1/2	1/2										
1 1/4	5/8	1/2	5/8	1/2	5/8	1/2	5/8	5/8						
1 1/2	5/8	1/2	3/4	9/16	3/4	1/2	3/4	5/8						
1 3/4	5/8	1/2	3/4	9/16	3/4	5/8	7/8	3/4	7/8	3/4				
2	3/4	1/2	3/4	9/16	3/4	5/8	7/8	3/4	7/8	7/8				
2 1/4	3/4	1/2	3/4	9/16	3/4	5/8	7/8	3/4	7/8	7/8	1	1		
2 1/2	3/4	1/2	3/4	9/16	3/4	5/8	7/8	3/4	7/8	7/8	1 1/8	1	1 1/4	1 1/8
2 3/4	3/4	1/2	3/4	9/16	7/8	3/4	1	7/8	1	7/8	1 1/8	1	1 1/4	1 1/8
3	3/4	1/2	7/8	9/16	7/8	3/4	1	7/8	1	7/8	1 1/8	1	1 1/4	1 1/8
3 1/4			7/8	9/16	1	3/4	1	7/8	1	7/8	1 1/8	1	1 1/4	1 1/8
3 1/2			7/8	9/16	1	3/4	1	7/8	1 1/4	7/8	1 1/4	1	1 1/4	1 1/8
3 3/4			1	11/16	1	3/4	1 1/4	7/8	1 1/4	7/8	1 1/4	1	1 1/4	1 1/8
4			1	11/16	1 1/4	3/4	1 1/4	7/8	1 1/4	1	1 1/4	1	1 1/2	1 1/4
4 1/4					1 1/4	7/8	1 1/4	7/8	1 1/2	1	1 1/2	1 1/8	1 1/2	1 1/4
4 1/2					1 1/4	7/8	1 1/4	7/8	1 1/2	1	1 1/2	1 1/8	1 3/4	1 1/4
4 3/4					1 1/4	7/8	1 1/4	7/8	1 1/2	1	1 1/2	1 1/8	1 3/4	1 1/4
5					1 1/4	7/8	1 1/2	7/8	1 1/2	1	1 3/4	1 1/8	2	1 1/4
5 1/4							1 1/2	7/8	1 1/2	1	1 3/4	1 1/8	2	1 1/2
5 1/2							1 1/2	7/8	1 3/4	1	1 3/4	1 1/8	2	1 1/2
5 3/4							1 1/2	7/8	1 3/4	1	1 3/4	1 1/4	2	1 1/2
6							1 1/2	7/8	1 3/4	1	1 3/4	1 1/4	2	1 1/2

Drilling a Cored Hole

Castings having cored holes are usually drilled with a four lip drill. The hole in the casting should be beveled, as shown in Fig. 1 to start the drill true; otherwise, the drill will follow the cored hole and may be thrown off center. For accurate drilling it is advisable to counterbore the hole a short depth to give the drill point a perfectly concentric starting point.

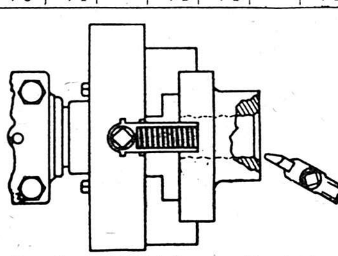


Fig. 1 Machining a Bevel in Cored Hole to Start Drill True

MACHINE SCREWS — TAP DRILL

Size of Tap	Size of Drill for Outside Diam. of Screw	Size of Drill for Tapping Hole	Size of Tap	Size of Drill for Outside Diam. of Screw	Size of Drill for Tapping Hole	Size of Tap	Size of Drill for Outside Diam. of Screw	Size of Drill for Tapping Hole
2x48		50	9x24		30	16x16		12
2x56	44	49	9x28	16	28	16x18	I	8
2x64		48	9x30		28	16x20		7
			9x32		26			
						17x16		8
3x40		49				17x18	L	4
3x48	39	47	10x24		26	17x20		3
3x56		45	10x30	11	24			
			10x32		24	18x16		2
6x32		46				18x18	19/64	2
6x36	33	44	11x24		21	18x20		1
6x40		43	11x28	6	20			
			11x30		19	19x16		1
						19x18	5/16	B
5x30		43				19x20		C
5x32		42	12x20		24			
5x36	1/8	41	12x22		20	20x16		C
5x40		38	12x24	7/32	19	20x18	P	E
			12x28		18	20x20		F
6x30		38				22x16	S	H
6x32		37	13x20		17	22x18		J
6x36	28	36	13x22	15/64	17			
6x40		35	13x24		15	24x14		L
						24x16	3/8	M
						24x18		N
7x28		34	14x20		15	26x14		O
7x30	24	33	14x22	1/4	11	26x16	13/32	P
7x32		32	14x24		10			
						28x14		R
			15x18		12	28x16	7/16	S
8x24		31	15x20		10			
8x30	19	31	15x22	F	8	30x14	29/64	U
8x32		30	15x24		7	30x16		V

Tapping Threads

Threads may be tapped in the lathe, using a tap as shown in Fig. 1. The lathe spindle should be operated at slow speed and the tap fed to the work by turning the tailstock handwheel, or by sliding the entire tailstock on the lathe bed. Taps may also be held in a drill chuck.

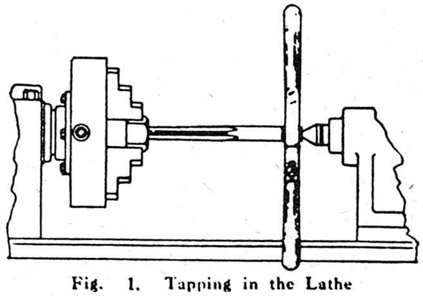


Fig. 1. Tapping in the Lathe

THREAD CUTTING AND FINISHING

Resetting Tool After Cut Has Been Started

If for any reason it is necessary to remove the thread cutting tool before the thread has been completed, the tool must be carefully readjusted so that it will follow the original groove when it is replaced in the lathe.

Before adjusting the tool, take up all the lost motion by pulling the belt forward by hand.

The compound rest top should be set at an angle, and by adjusting the cross feed screw and compound rest feed screw simultaneously the point of the tool can be made to enter exactly into the original groove.

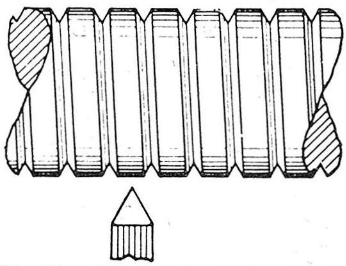


Fig. 38. Adjusting Point of Threading Tool to Conform with Thread

Finishing the End of a Thread

The end of the thread may be finished by any one of several methods. The 45° chamfer on the end of the thread, as shown in Fig. 39 is commonly used for bolts, cap screws, etc. For machine parts and special screws the end is often finished by rounding with a forming tool, as shown in Fig. 40.

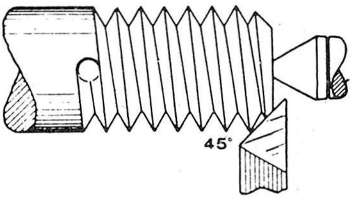


Fig. 39. Finish End of Thread with 45° Chamfer

It is difficult to stop the threading tool abruptly so some provision is usually made for clearance at the end of the cut. In Fig. 39 a hole has been drilled in the end of the shaft, and in Fig. 40 a neck or groove has been cut around the shaft. The groove is preferable as the lathe must be run very slowly in order to obtain satisfactory results with the drilled hole.

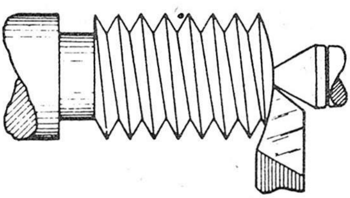


Fig. 40. Finishing End of Thread with Forming Tool

Cutting Multiple Screw Threads

A multiple thread having two grooves is known as a double thread, three threads a triple thread, etc. (See Fig. 41) The pitch and lead of a multiple thread should not be confused. The pitch is the distance from a point on one thread to the corresponding point on the next thread, while the lead is the distance a screw thread advances in one turn.

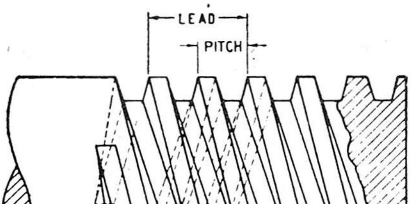


Fig. 41. A Multiple Screw Thread Having Two Grooves (Double Thread)

When cutting multiple threads in the lathe the first thread is cut to the desired depth. The work is then revolved part of a turn, and the second thread cut, etc. In order to obtain an exact spacing it is advisable to mill as many equally spaced slots in the face plate for the lathe dog as there are multiple threads to be cut. For a double thread, two slots; a triple thread, three slots, etc. If it is not convenient to cut slots in the face plate, equally spaced studs may be attached to the face plate and a straight tail lathe dog used.

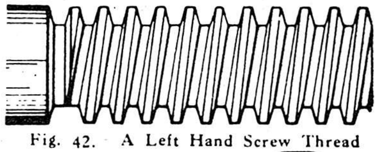


Fig. 42. A Left Hand Screw Thread

Cutting a Left Hand Screw Thread

A left hand screw is one that turns counter-clockwise when advancing (looking at head of screw) as shown in Fig. 43. This is just the opposite of a right hand screw. Left hand threads are used for the cross feed screws of lathes, the left hand end of axles for automobiles and wagons, one end of a turnbuckle, some pipe threads, etc.

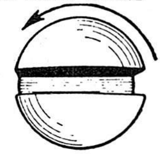


Fig. 43. A Left Hand Screw Advances When Turned Counter-clockwise

In cutting left hand screw threads the lathe is set up exactly the same as for cutting right hand screw threads, except that the lathe must be arranged to feed the tool from left to right, instead of from right to left, when the spindle is revolving forward.

Square Screw Threads

Square threads are used for vice screws, jack screws, etc. The sides of the tool for cutting square threads should be ground at an angle to conform with the helix angle of the thread, as shown in Fig. 44

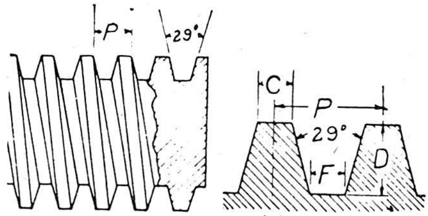


Fig. 44. A 29° Worm Thread Form

To determine the helix angle of a screw thread, draw line A-C2 equal to the circumference of the thread to be cut. Draw line C2-C equal to the lead of the thread and at right angles to line A-C2. Complete the triangle by drawing line A-C. Angle B in the triangle is the helix angle of the thread. The sides of the tool E and F should be given a little clearance.

The width of the cutting edge of the tool for cutting square screw threads is exactly one-half the pitch, but the width of the tool for threading the nut should be from one thousandth to three thousandths of an inch larger, to permit a free fit on the screw.

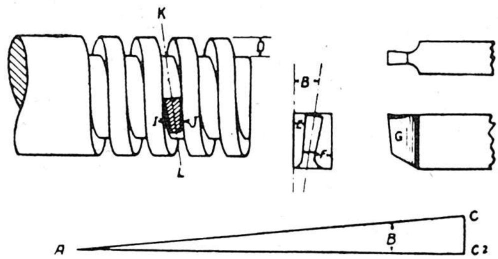
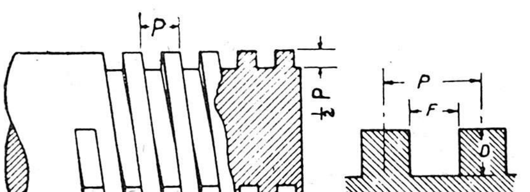


Fig. 44. Tool for Cutting Square Threads



FORMULA

P Pitch = $\frac{1}{\text{No. Th'ds. Per In.}}$

D = Depth = P. x .500

F = Space = P. x .500

Fig. 45. Design and Proportions of Square Screw Threads

A 29° Worm Thread should not be confused with the Acme Standard Thread because it differs in the depth of the thread, the width of the top of the tooth and the width of the bottom of the tooth, as shown above. Fig. 44 "A"

29° Worm Thread
(Brown & Sharpe)
FORMULA

P = Pitch = $\frac{1}{\text{No. Th'ds. Per In.}}$

D = Depth = .6866 P.

F = Flat = .31 P.

C = Flat = .335 P.

Measuring Screw Threads

To check the number of threads per inch, place a scale against the work, as shown in Fig. 1 so that the end of the scale rests on the point of the thread or on one of the scribed lines. Count the spaces between the end of the scale and the first inch mark, and this will give you the number of threads per inch. Fig. 1 shows eight threads per inch.

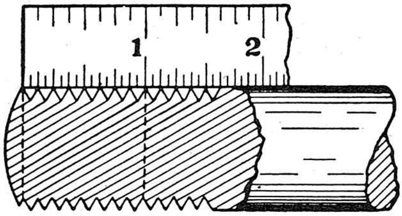


Fig. 1 Measuring Screw Threads

Taking the First Cut

After setting up the lathe, as explained on the preceding pages, take a very light trial cut just deep enough to scribe a line on the surface of the work, as shown in Fig. 2 The purpose of this trial cut is to make sure the lathe is arranged for cutting the desired pitch of thread.

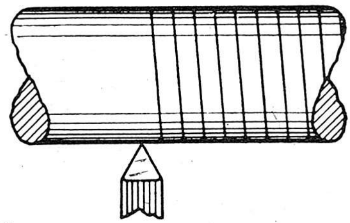


Fig. 2 Trial Cut to Check the Set-up for Thread Cutting

Pitch Diameter and Root Diameter of Screw Threads

To find the pitch diameter or root diameter of any screw thread, subtract the constant for the number of threads per inch from the outside diameter.

Threads per Inch	Constants for Finding Pitch Diameter			Constants for Finding Root Diameter		
	National Thread	Whitworth Thread	Theoretical V	National Thread	Whitworth Thread	Theoretical V
72	.00902	.00889	.01203	.01804	.01786	.02406
64	.01015	.01000	.01353	.02030	.02001	.02706
60	.01083	.01067	.01443	.02165	.02134	.02887
56	.01160	.01144	.01546	.02320	.02286	.03093
50	.01299	.01281	.01732	.02598	.02562	.03464
48	.01353	.01334	.01804	.02706	.02668	.03608
44	.01476	.01455	.01968	.02952	.02910	.03936
40	.01624	.01601	.02165	.03248	.03202	.04330
36	.01804	.01779	.02406	.03608	.03558	.04811
32	.02030	.02001	.02706	.04059	.04002	.05413
30	.02165	.02134	.02887	.04330	.04268	.05773
28	.02320	.02287	.03093	.04639	.04574	.06186
27	.02406	.02372	.03207	.04812	.04742	.06416
26	.02498	.02463	.03331	.04996	.04926	.06662
24	.02706	.02668	.03608	.05413	.05336	.07217
22	.02952	.02911	.03936	.05905	.05821	.07873
20	.03248	.03202	.04330	.06495	.06403	.08660
18	.03608	.03557	.04811	.07217	.07114	.09623
16	.04059	.04002	.05413	.08119	.08004	.10825
14	.04639	.04574	.06186	.09279	.09147	.12372
13	.04996	.04926	.06662	.09993	.09851	.13323
12	.05413	.05336	.07217	.10825	.10672	.14434
11½	.05648	.05568	.07531	.11296	.11132	.15062
11	.05905	.05821	.07873	.11809	.11642	.15746
10	.06495	.06403	.08660	.12990	.12806	.17321
9	.07217	.07115	.09623	.14434	.14230	.19245
8	.08119	.08004	.10825	.16238	.16008	.21651
7	.09279	.09148	.12372	.18558	.18295	.24744
6	.10825	.10672	.14434	.21651	.21344	.28868
5¼	.11809	.11642	.15746	.23619	.23284	.31492
5	.12990	.12807	.17321	.25981	.25613	.34641
4½	.14434	.14230	.19245	.28868	.28458	.28490
4	.16238	.16008	.21651	.32476	.32017	.43301
3½	.18558	.18295	.24744	.37115	.36590	.49487
3¼	.19985	.19702	.26647	.39970	.39404	.53294
3	.21651	.21344	.28868	.43301	.42689	.57733

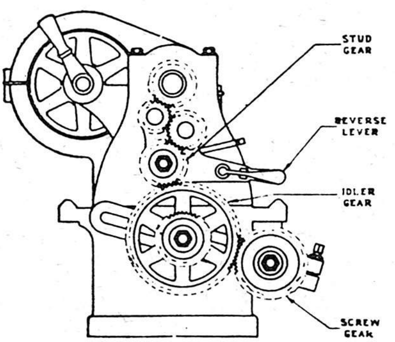


Fig. 1 Simple gearing

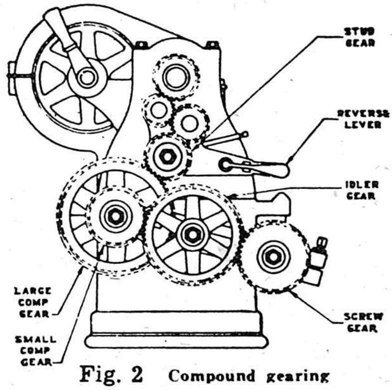


Fig. 2 Compound gearing

How to Calculate Change Gears for Thread Cutting

If it is necessary to cut a special thread that does not appear on the index chart of a lathe or if no index chart is available, the gears required can easily be calculated. If simple gearing is to be used, as shown; that is, the stud gear revolves the same number of revolutions as the headstock spindle, and when gears of the same size are used on both the lead screw and stud, the lead screw and spindle revolve the same number of revolutions, so it is not necessary to consider the gearing between the headstock spindle and the stud gear when calculating change gears.

If simple gearing is to be used, as shown in Fig. 1 the ratio of the number of teeth in the change gears used will be the same as the ratio between the thread to be cut and the thread on the lead screw. For example, if 10 threads per inch are to be cut on a lathe having a lead screw with 6 threads per inch, the ratio of the change gears would be 6 to 10. These numbers may be multiplied by any common multiplier to obtain the number of teeth in the change gears that should be used.

Rule—To calculate change gears, multiply the number of threads per inch to be cut and the number of threads per inch in the lead screw by the same number.

Example: Problem—To cut 10 threads per inch on lathe having lead screw with 6 threads per inch.

Solution— 6 x 8 = 48 — No. of teeth in gear on stud.
10 x 8 = 80 — No. of teeth in gear on lead screw.

If these gears are not to be found in the change gear set, any other number may be used as a common multiplier, such as 3, 5, 7, etc.

When compound gearing, as shown in Fig. 2 is used, the ratio of the compound idler gears must also be taken into consideration, but otherwise the calculations are the same as for simple gearing. Usually, the compound idler gear ratio is 2 to 1, so that the threads cut are just twice the number per inch as when simple gearing is used.

Types of Pulleys—Two types of pulleys are used for flat belts, the crowned face pulley and the flat face pulley. Crowned pulleys should always be used if possible, as it is the crown that keeps the belt on the pulley. Flat face pulleys should be used only when it is necessary to shift the belt from one position on the pulley to another, as in a drum pulley or a wide faced pulley on a machine used to match a tight and loose pulley on a countershaft.

CHANGE GEARS FOR THREAD MILLING

Single Thread

Threads Per Inch	A	B	C	D	F	G	Threads Per Inch	A	B	C	D	F	G
40							10	36	20	20	30	1	96
39							9	40	20	20	30	1	96
38	20	38	24	40	1	96	8	36	20	20	24	1	96
36	20	36	24	40	1	96	7	30	21	24	20	1	96
35							6	40	24	36	30	1	96
34	20	34	24	40	1	96	5½	40	20	24	22	1	96
32	20	32	24	40	1	96	5	40	20	24	20	1	96
30	20	30	24	40	1	96	4½	24	20	20	36	1	24
29	20	29	24	40	1	96	4	24	20	20	32	1	24
28	20	28	24	40	1	96	3½	24	20	20	28	1	24
27	20	27	24	40	1	96	3¼	24	20	20	26	1	24
26	20	26	24	40	1	96	3	36	24	20	30	1	24
25	20	25	24	40	1	96	2⅞	24	20	20	23	1	24
24	30	36	24	40	1	96	2¾	36	22	20	30	1	24
23	24	23	20	40	1	96	2⅝	32	20	20	28	1	24
22	24	22	20	40	1	96	2½	30	20	20	25	1	24
21	24	21	20	40	1	96	2⅜	24	38	40	20	1	24
20	24	20	20	40	1	96	2¼	40	20	20	30	1	24
19	24	20	20	38	1	96	2⅛	40	20	24	34	1	24
18	24	20	20	36	1	96	2	40	20	24	32	1	24
17	24	20	20	34	1	96	1⅞	40	20	24	30	1	24
16	24	20	20	32	1	96	1¾	30	21	24	20	1	24
15	24	20	20	30	1	96	1⅝	40	20	24	26	1	24
14	24	20	20	28	1	96	1½	40	24	36	30	1	24
13	24	20	20	26	1	96	1⅜	40	20	24	22	1	24
12	36	24	20	30	1	96	1¼	40	20	24	20	1	24
11½	24	20	20	23	1	96	1⅛	40	20	28	21	1	24
11	30	20	20	40	1	96	1	21	28	20	40	8	24

Double Thread

Threads per Inch	A	B	C	D	F	G	Threads per Inch	A	B	C	D	F	G
40	24	20	20	40	1	96	10	24	20	20	40	1	24
39	32	26	20	40	1	96	9	24	20	20	36	1	24
38	24	20	20	38	1	96	8	30	20	20	40	1	24
36	24	20	20	36	1	96	7	24	20	20	28	1	24
35	20	25	24	28	1	96	6	36	24	20	30	1	24
34	24	20	20	34	1	96	5½	36	22	20	30	1	24
32	24	20	20	32	1	96	5	30	20	20	25	1	24
30	24	20	20	30	1	96	4½	40	20	20	30	1	24
29	24	20	20	29	1	96	4	40	20	24	32	1	24
28	24	20	20	28	1	96	3½	30	21	24	20	1	24
27	24	20	20	27	1	96	3¼	40	20	24	26	1	24
26	24	20	20	26	1	96	3	40	24	36	30	1	24
25	24	20	20	25	1	96	2⅞	40	20	24	23	1	24
24	36	24	20	30	1	96	2¾	40	20	24	22	1	24
23	24	20	20	23	1	96	2⅝	40	20	24	21	1	24
22	36	22	30	30	1	96	2½	40	20	30	25	1	24
21	32	20	20	8	1	96	2⅜	20	40	24	38	8	24
20	36	20	20	30	1	96	2¼	20	30	20	40	8	24
19	20	38	24	40	1	24	2⅛	20	34	24	40	8	24
18	20	36	24	40	1	24	2	20	23	21	40	8	24
17	20	34	24	40	1	24	1⅞	20	30	24	40	8	24
16	20	32	24	40	1	24	1¾	20	28	24	40	8	24
15	20	30	24	40	1	24	1⅝	20	26	24	40	8	24
14	20	28	24	40	1	24	1½	21	28	24	36	8	24
13	20	26	24	40	1	24	1⅜	20	22	24	40	8	24
12	20	28	21	30	1	24	1¼	20	25	21	28	8	24
11½	24	23	20	40	1	24	1⅛	20	36	24	20	8	24
11	24	22	20	40	1	24	1	30	20	20	40	8	24

CAUTION — See That Table Trip Lever is Locked.

Kearney & Trecker Corporation, Milwaukee, Wis.
Change Gears for Thread Milling—

CHANGE GEARS FOR THREAD MILLING

Triple Thread

Threads per Inch	A	B	C	D	F	G	Threads per Inch	A	B	C	D	F	G
40	36	20	20	40	1	96	10	27	20	20	30	1	24
39	24	20	20	26	1	96	9	25	20	24	30	1	24
38	36	20	20	38	1	96	8	27	20	20	24	1	24
36	36	24	20	30	1	96	7	36	20	20	28	1	24
35	36	25	20	28	1	96	6	36	20	20	24	1	24
34	36	20	20	34	1	96	5½	36	20	20	22	1	24
33	36	22	20	30	1	96	5	40	20	27	30	1	24
32	30	20	24	32	1	96	4½	32	20	25	20	1	24
30	36	20	20	30	1	96	4	36	32	40	20	1	24
29	36	20	20	29	1	96	3½	40	20	27	21	1	24
28	36	20	20	28	1	96	3¼	40	20	36	26	1	24
27	36	20	20	27	1	96	3	40	20	36	24	1	24
26	36	20	20	26	1	96	2⅞	40	20	36	23	1	24
25	36	20	20	25	1	96	2¾	40	20	36	22	1	24
24	36	20	20	24	1	96	2⅝	24	28	20	40	8	24
23	36	20	20	23	1	96	2½	24	28	21	40	8	24
22	36	20	20	22	1	96	2⅜	24	38	30	40	8	24
21	36	20	20	21	1	96	2¼	24	30	25	40	8	24
20	30	20	24	20	1	96	2⅛	21	28	24	34	8	24
19	36	38	40	20	1	96	2	21	40	30	28	8	24
18	30	20	28	21	1	96	1⅞	24	20	20	40	8	24
17	40	20	36	34	1	96	1¾	30	28	24	40	8	24
16	36	20	30	24	1	96	1⅝	21	26	24	28	8	24
15	24	20	20	40	1	24	1½	30	20	20	40	8	24
14	20	40	36	28	1	24	1⅜	21	22	24	28	8	24
13	20	30	27	26	1	24	1¼	30	20	24	40	8	24
12	30	20	20	40	1	24	1⅛	30	24	20	25	8	24
11½	20	40	36	23	1	24	1	36	24	30	40	8	24
11	27	22	20	30	1	24							

Kearney & Trecker Corp.

Quadruple Thread

Threads per Inch	A	B	C	D	F	G	Threads per Inch	A	B	C	D	F	G
40	36	20	20	30	1	96	10	36	20	20	30	1	24
39	40	30	24	26	1	96	9	36	20	20	27	1	24
38	40	20	24	38	1	96	8	36	20	20	24	1	24
36	40	20	20	30	1	96	7	36	20	20	21	1	24
35	36	21	20	25	1	96	6	36	30	40	24	1	24
34	40	20	24	34	1	96	5½	40	22	24	20	1	24
33	40	22	24	30	1	96	5	36	30	40	20	1	24
32	40	20	24	32	1	96	4½	24	36	20	40	8	24
30	24	30	20	40	1	24	4	24	32	20	40	8	24
29	24	29	20	40	1	24	3½	24	28	20	40	8	24
28	24	28	20	40	1	24	3¼	24	26	20	40	8	24
27	24	27	20	40	1	24	3	30	36	24	40	8	24
26	24	26	20	40	1	24	2⅞	24	23	20	40	8	24
25	24	25	20	40	1	24	2¾	24	22	20	40	8	24
24	24	40	20	36	1	24	2⅝	24	21	20	40	8	24
23	24	23	20	40	1	24	2½	24	20	20	40	8	24
22	24	22	20	40	1	24	2⅜	24	20	20	38	8	24
21	20	25	20	28	1	24	2¼	24	20	20	36	8	24
20	24	20	20	40	1	24	2⅛	24	20	20	34	8	24
19	24	20	20	38	1	24	2	24	20	20	32	8	24
18	24	20	20	36	1	24	1⅞	24	20	20	30	8	24
17	24	20	20	34	1	24	1¾	24	20	20	28	8	24
16	24	20	20	32	1	24	1⅝	24	20	20	26	8	24
15	24	20	20	30	1	24	1½	30	24	20	25	8	24
14	24	20	20	28	1	24	1⅜	36	22	20	30	8	24
13	24	20	20	26	1	24	1¼	36	20	20	30	8	24
12	20	25	30	24	1	24	1⅛	36	20	20	27	8	24
11½	24	20	20	23	1	24	1	36	20	20	24	8	24
11	24	20	20	22	1	24							

CAUTION — See That Table Trip Lever is Locked.

—Sizes of Tap Drills, American National Coarse-Thread Series

Size of thread	Threads per inch	Minor diameter of nut			Stock drills corresponding to 100 percent to 50 percent of basic thread depth		
		Basic	Maximum	Minimum	Nominal size	Diameter	Percentage of depth of basic thread
5	40	.0925	.1062	.0979	#39	.0995	79
					#38	.1015	72
					2.60 mm	.1024	70
					#37	.1040	65
6	32	.0974	.1145	.1042	#36	.1065	78
					7/64 in	.1094	70
					#33	.1130	62
8	32	.1234	.1384	.1302	3.40 mm	.1339	74
					#29	.1360	69
					3.50 mm	.1378	65
10	24	.1359	.1559	.1449	#26	.1470	79
					#24	.1520	70
12	24	.1619	.1801	.1709	11/64 in	.1719	82
					#17	.1730	79
					#16	.1770	72
					#15	.1800	67
¼	20	.1850	.2060	.1959	#9	.1960	83
					#8	.1990	79
					13/64 in	.2031	72
5/16	18	.2403	.2630	.2524	F	.2570	77
					G	.2610	71
⅜	16	.2938	.3184	.3073	5/16 in	.3125	77
					O	.3160	73
7/16	14	.3447	.3721	.3602	U	.3680	75
½	13	.4001	.4290	.4167	27/64 in	.4219	78
9/16	12	.4542	.4850	.4723	31/64 in	.4844	72
		Inch	*Inch*	*Inch*		*Inch*	
⅝	11	.5069	.5397	.5266	17/32 in	.5312	79
					13.5 mm	.5315	79
¾	10	.6201	.6553	.6417	16.5 mm	.6496	77
⅞	9	.7307	.7689	.7547	49/64 in	.7656	76
					19.5 mm	.7677	74
1	8	.8376	.8795	.8647	22 mm	.8661	82
					⅞ in	.8750	77
1⅛	7	.9394	.9858	.9704	25 mm	.9842	76
					63/64 in	.9844	76
1¼	7	1.0644	1.1108	1.0954	28 mm	1.1024	80
					1 7/64 in	1.1094	76
1⅜	6	1.1585	1.2126	1.1946	30.5 mm	1.2008	80
					1 13/64 in	1.2031	79
1½	6	1.2835	1.3376	1.3196	1 21/64 in	1.3281	79
1¾	5	1.4902	1.5551	1.5335	39 mm	1.5354	83
					1 35/64 in	1.5469	78
					39.5 mm	1.5551	75
2	4½	1.7113	1.7835	1.7594	1 49/64 in	1.7656	81
					45 mm	1.7716	79
					1 25/32 in	1.7812	76

—Sizes of Tap Drills, American National Fine-Thread Series

Size of thread	Threads per inch	Minor diameter of nut			Stock drills corresponding to 100 percent to 50 percent of basic thread depth		
		Basic	Maximum	Minimum	Nominal size	Diameter	Percentage of depth of basic thread
5	44	.0955	.1068	.1004	2.60 mm #37 #36	.1024 .1040 .1065	77 71 63
6	40	.1055	.1179	.1109	#33 #32	.1130 .1160	77 68
8	36	.1279	.1402	.1339	3.40 mm #29 3.50 mm 9/64 in	.1339 .1360 .1378 .1406	83 78 73 65
10	32	.1494	.1624	.1562	5/32 in #21 #20 #19	.1562 1590 .1610 .1660	83 76 71 59
12	28	.1696	.1835	.1773	#15 4.70 mm #13 3/16 in	.1800 .1850 .1875	78 67 61
1/4	28	.2036	.2173	.2113	#3	.2130	80
5/16	24	.2584	.2739	.2674	17/64 in I	.2656 .2720	87 75
3/8	24	.3209	.3364	.3299	Q	.3320	79
		Inch	*Inch*	*Inch*		*Inch*	
7/16	20	0.3725	0.3906	0.3834	W 25/64 in	0.3860 .3906	79 72
1/2	20	.4350	.4531	.4459	29/64 in	.4531	72
9/16	18	.4903	.5100	.5024	0.5062	.5062	78
5/8	18	.5528	.5725	.5649	14.5 mm	.5709	75
3/4	16	6688	.6903	.6823	11/16 in 17.5 mm	.6875 .6890	77 75
7/8	14	.7822	.8062	.7977	51/64 in 20.5 mm	.7969 .8071	84 73
1	14	.9072	.9312	.9227	23.5 mm	.9252	81
1 1/8	12	1.0167	1.0438	1.0348	26.5 mm	1.0433	75
1 1/4	12	1.1417	1.1688	1.1598	29.5 mm	1.1614	82
1 3/8	12	1.2667	1.2938	1.2848	41/32 in 1 19/64 in	1.2812 1.2969	8 72
1 1/2	12	1.3917	1.4188	1.4098	36 mm	1.4173	76

Tap drill size for 75% full thread for ANY American National Thread equals major diameter minus pitch in inches.

Table of Speeds and Feeds — For High Speed Drills

Diameter of Drill	Feed per Revolution	Mild Steel	Tool Steel	Cast Iron	Brass and Bronze	Drop Forgings
		Cutting Speed, Feet per Minute				
		120 Feet	60 Feet	140 Feet	300 Feet	60 Feet
		REVOLUTIONS PER MINUTE				
1/16	.003	7334	3666	8566	18336	3666
3/32	.0035	5500	2750	6417	13750	2750
1/8	.004	3666	1834	4278	9168	1834
5/32	.0045	3055	1528	3565	7640	1528
3/16	.005	2444	1222	2852	6112	1222
7/32	.0055	2139	1069	2496	5348	1069
1/4	.006	1834	916	2140	4584	916
9/32	.0065	1650	825	1926	4125	825
5/16	.007	1466	734	1712	3666	734
11/32	.0075	1344	673	1569	3361	673
3/8	.008	1222	612	1426	3056	612
13/32	.0085	1135	568	1324	2838	568
7/16	.009	1048	524	1222	2620	524
15/32	.0095	982	491	1146	2456	491
1/2	.010	916	458	1070	2292	458
9/16	.0105	825	412	963	2063	412
5/8	.011	734	366	856	1834	366
11/16	.0115	673	336	785	1681	336
3/4	.012	612	306	714	1528	306
13/16	.0125	568	284	663	1419	284
7/8	.013	524	262	612	1310	262
15/16	.0135	491	246	573	1228	246
1	.014	458	230	534	1146	230
1 1/8	.015	408	204	476	1018	204
1 1/4	.016	366	184	428	916	184
1 3/8	.016	334	166	388	834	166
1 1/2	.016	306	152	356	764	152
1 5/8	.016	282	140	330	706	140
1 3/4	.016	262	130	306	654	130
1 7/8	.016	244	122	286	612	122
2	.016	230	114	268	574	114

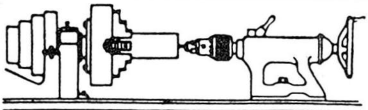


Fig. 1

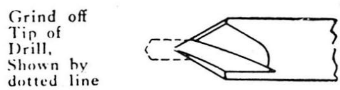


Fig. 2

Center Drilling

When greater accuracy is required it is best to provide a true starting point for the drill. To do this the work should first be center drilled using a combination center drill and countersink, as shown in Fig. 1. The point of the center drill may be ground off as shown in Fig. 2 to prevent breaking.

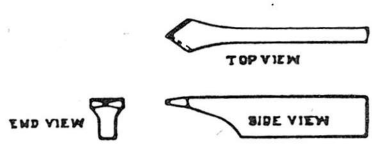


Fig. 3

Flat Centering Drill

A flat centering tool or drill of forged steel held rigidly in the tool post of the lathe, as shown in Figs. 3 and 4 is often used for production drilling. This type of centering drill provides an accurate starting point for the drill, and since the centering drill is mounted in the tool post, it may be moved back out of the way for the drill which is to follow. This saves time as it eliminates the necessity of changing drills in the tailstock spindle

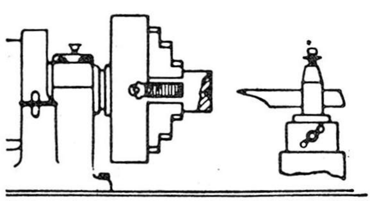


Fig. 4

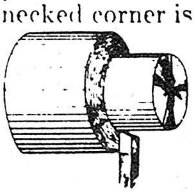
Table of Speeds and Feeds
For Carbon Steel Drills

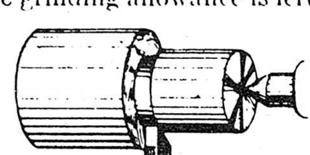
Diameter of Drill	Feed per Revolution	Mild Steel	Tool Steel	Cast Iron	Brass and Bronze	Drop Forging
		Cutting Speed, Feet per Minute				
		60 Feet	30 Feet	70 Feet	150 Feet	30 Feet
		REVOLUTIONS PER MINUTE				
1/16	.003	3667	1833	4278	9168	1833
3/32	.0035	2750	1375	3208	6875	1375
1/8	.004	1833	917	2139	4584	917
5/32	0045	1527	764	1782	3820	764
3/16	.005	1222	611	1426	3056	611
7/32	.0055	1069	534	1248	2674	534
1/4	.006	917	458	1070	2292	458
9/32	.0065	825	412	963	2062	412
5/16	.007	733	367	856	1833	367
11/32	.0075	672	336	784	1680	336
3/8	.008	611	306	713	1528	306
13/32	.0085	567	284	662	1419	284
7/16	.009	524	262	611	1310	262
15/32	.0095	491	245	573	1228	245
1/2	.010	458	229	535	1146	229
9/16	.0105	412	206	481	1031	206
5/8	.011	367	183	428	917	183
11/16	.0115	336	168	392	840	168
3/4	.012	306	153	357	764	153
13/16	.0125	284	142	331	709	142
7/8	.013	262	131	306	655	131
15/16	.0135	245	123	286	614	123
1	.014	229	115	267	573	115
1 1/8	.015	204	102	238	509	102
1 1/4	016	183	92	214	458	92
1 3/8	.016	167	83	194	417	83
1 1/2	.016	153	76	178	382	76
1 5/8	016	141	70	165	353	70
1 3/4	.016	131	65	153	327	65
1 7/8	.016	122	61	143	306	61
2	.016	115	57	134	287	57

Shoulder and Radius Forming

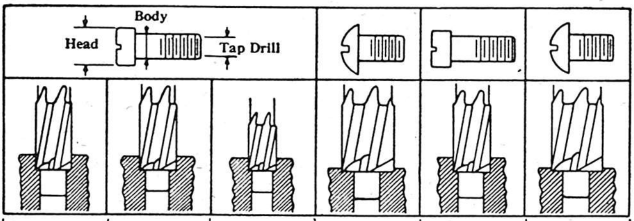
The corners in turned work are at various times finished square, necked, either square or round, or with a small radius. Also with square or radius tool at an angle of 45° to allow clearance for grinding both diameter and face.

The square corner is the simplest type and is used where the piece is not subject to excess stress at the corner section. The necked corner is used as above, also where grinding allowance is left in turning. The under-cut neck prevents undue wear on the corner of the grinding wheel.





Counterbore Sizes for Cap Screws and Machine Screws



Size Thread N.F. and N.C.	Fillister Head Cap Screw — Head and Body: Cutter for Head	Fillister Head Cap Screw — Head and Body: Pilot for Body	Fillister Head Cap Screw — Head and Tap Hole: Cutter for Head	Fillister Head Cap Screw — Head and Tap Hole: Pilot for Tap Hole	Body and Tap Hole for any Screw: Cutter for Body	Body and Tap Hole for any Screw: Pilot for Tap Hole	Round or Hexagon Head Cap Screw — Head and Body: Cutter for Head	Round or Hexagon Head Cap Screw — Head and Body: Pilot for Body	Fillister Head Machine Screw — Head and Body: Cutter for Head	Fillister Head Machine Screw — Head and Body: Pilot for Body	Round or Hex. Head Machine Screw — Head and Body: Cutter for Head	Round or Hex. Head Machine Screw — Head and Body: Pilot for Body	Tap Drills
1/4-28	.375	.250	.375	.213	.250	.213	.500	.250	.437	.250	.500	.250	3
1/4-20	.375	.250	.375	.201	.250	.201	.500	.250	.437	.250	.500	.250	7
5/16-24	.437	.312	.437	.272	.312	.272	.625	.312	.531	.312	.625	.312	I
5/16-18	.437	.312	.437	.257	.312	.257	.625	.312	.531	.312	.625	.312	F
3/8-24	.562	.375	.562	.332	.375	.332	.687	.375	.625	.375	.750	.375	Q
3/8-16	.562	.375	.562	.312	.375	.312	.687	.375	.625	.375	.750	.375	5/16
7/16-20	.625	.437	.625	.390	.437	.390	.813	.437	.718	.437	.875	.437	25/64
7/16-14	.625	.437	.625	.368	.437	.368	.813	.437	.718	.437	.875	.437	U
1/2-20	.750	.500	.750	.453	.500	.453	.875	.500	.843	.500	1.000	.500	29/64
1/2-13	.750	.500	.750	.421	.500	.421	.875	.500	.843	.500	1.000	.500	27/64
9/16-18	.812	.562	.812	.515	.562	.515	1.000	.562					33/64
9/16-12	.812	.562	.812	.484	.562	.484	1.000	.562					31/64
5/8-18	.875	.625	.875	.578	.625	.578	1.062	.625					37/64
5/8-11	.875	.625	.875	.531	.625	.531	1.062	.625					17/32
3/4-16	1.000	.750	1.000	.687	.750	.687	1.312	.750					11/16
3/4-10	1.000	.750	1.000	.656	.750	.656	1.312	.750					21/32
7/8-14	1.125	.875	1.125	.812	.875	.812	1.375	.875					13/16
7/8-9	1.125	.875	1.125	.765	.875	.765	1.375	.875					49/64
1-14	1.312	1.000	1.312	.937	1.000	.937	1.500	1.000					15/16
1-8	1.312	1.000	1.312	.875	1.000	.875	1.500	1.000					7/8

Sizes of Wrenches to Use for Counterbores and Spot Facers

Range of Sizes of Counterbores Inches	Size of Wrench for Hollow Hexagon Set Screw Inches
1/4 to 11/32	1/16 Hex.
3/8 to 7/16	5/64 Hex.
15/32 to 11/16	3/32 Hex.
23/32 to 1 3/16	1/8 Hex.
1 7/32 to 1 15/16	5/32 Hex.
2 to 3	3/16 Hex.

The measurements used for the wrench are across the flat.

SHIELDS DECIMAL EQUIVALENTS

of Twist Drills, Drill Rods, Stub Steel Wire Gauges, and Letter Sizes of Drills

FOUR TABLES IN ONE

This Table is to Show the Difference Between the Sizes of Twist Drills, and Drill Rods; to Save Time and Mistakes

Number of Twist Drill Wire Gauge Drill Rod Letter Size of Drills.	Size of Number in Decimals of Twist Drills.	Size of Number in Decimals of Drill Rods Wire Gauge and Letter Size of Drills.	Number of Twist Drill Wire Gauge Drill Rod Letter Size of Drills.	Size of Number in Decimals of Twist Drills.	Size of Number in Decimals of Drill Rods Wire Gauge and Letter Size of Drills.	Number of Twist Drill Wire Gauge Drill Rod Letter Size of Drills.	Size of Number in Decimals of Twist Drills.	Size of Number in Decimals of Drill Rods Wire Gauge and Letter Size of Drills.
1	.2280	.227	37	.1040	.103	73	.0240	.023
2	.2210	.219	38	.1015	.101	74	.0225	.022
3	.2130	.212	39	.0995	.099	75	.0210	.020
4	.2090	.207	40	.0980	.097	76	.0200	.018
5	.2055	.204	41	.0960	.095	77	.0180	.016
6	.2040	.201	42	.0935	.092	78	.0160	.015
7	.2010	.199	43	.0890	.088	79	.0145	.014
8	.1990	.197	44	.0860	.085	80	.0135	.013
9	.1960	.194	45	.0820	.081			
10	.1935	.191	46	.0810	.079			
11	.1910	.188	47	.0785	.077	A 15/64	.234	.234
12	.1890	.185	48	.0760	.075	B	.238	.238
13	.1850	.182	49	.0730	.072	C	.242	.242
14	.1820	.180	50	.0700	.069	D	.246	.246
15	.1800	.178	51	.0670	.066	E 1/4	.250	.250
16	.1770	.175	52	.0635	.063	F	.257	.257
17	.1730	.172	53	.0595	.058	G	.261	.261
18	.1695	.168	54	.0550	.055	H 17/64	.266	.266
19	.1660	.164	55	.0520	.050	I	.272	.272
20	.1610	.161	56	.0465	.045	J	.277	.277
21	.1590	.157	57	.0430	.042	K 9/32	.281	.281
22	.1570	.155	58	.0420	.041	L	.290	.290
23	.1540	.153	59	.0410	.040	M 19/64	.295	.295
24	.1520	.151	60	.0400	.039	N	.302	.302
25	.1495	.148	61	.0390	.038	O 5/16	.316	.316
26	.1470	.146	62	.0380	.037	P 21/64	.323	.323
27	.1440	.143	63	.0370	.036	Q	.332	.332
28	.1405	.139	64	.0360	.035	R 11/32	.339	.339
29	.1360	.134	65	.0350	.033	S	.348	.348
30	.1285	.127	66	.0330	.032	T 23/64	.358	.358
31	.1200	.120	67	.0320	.031	U	.368	.368
32	.1160	.115	68	.0310	.030	V 3/8	.377	.377
33	.1130	.112	69	.02925	.029	W 25/64	.386	.386
34	.1110	.110	70	.0280	.027	X	.397	.397
35	.1100	.108	71	.0260	.026	Y 13/32	.404	.404
36	.1065	.106	72	.0250	.024	Z	.413	.413

Use Turpentine instead of oil, when drilling hard steel, saw plate, etc. It will drill readily, when you could not touch it with oil. Try it.

TWIST DRILLS, GRINDING AND GAUGES

Grinding of Twist Drills

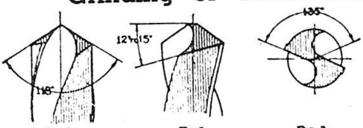


FIG. 1 FIG. 2 FIG. 3

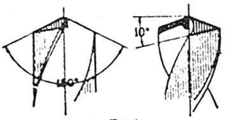


FIG. 4

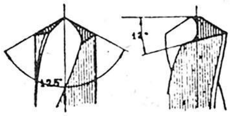


FIG. 5

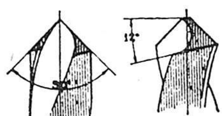


FIG. 6

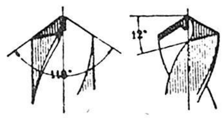


FIG. 7

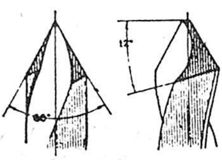


FIG. 8

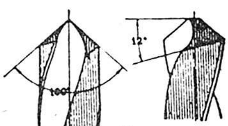


FIG. 9

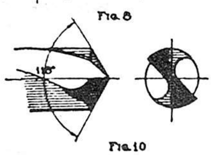
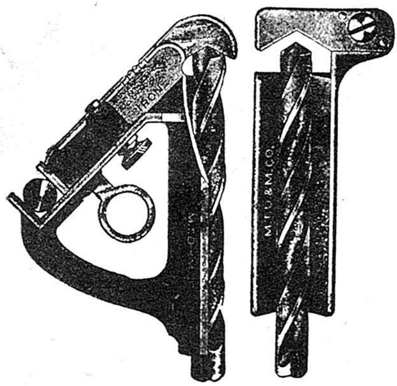


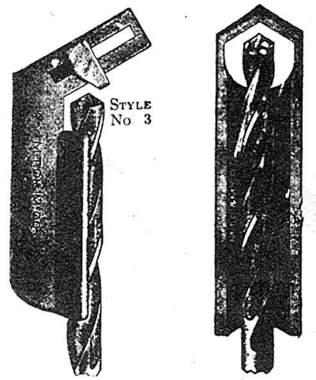
FIG. 10

DIPPING HIGH SPEED DRILLS IN WATER IS BAD PRACTICE

GAUGES FOR GRINDING DRILLS

STYLE No. 1 STYLE No. 2





STYLE No. 3

ANGLE OF POINTS

		Point
Steel Rails 7%-13% Manganese and hard materials	Fig. 4	150° included angle 10° lip clearance Slightly flat face of cutting lips.
Heat Treated Steels—Drop Forgings (Automobile Connecting Rods) Brinell Hardness No. 250	Fig. 5	125° included angle 12° lip clearance
Cast Iron—Soft	Fig. 6	90° included angle 12° lip clearance
Brass	Fig. 7	118° included angle 12° lip clearance Slightly flat face of cutting lips.
Wood	Fig. 8	60° included angle 12° lip clearance
Hard Rubber, Bakelite, Fiber	Figs. 6 & 8	60° and 90° included angle
Copper	Fig. 9	100° included angle 12° lip clearance
Crankshafts	Fig. 10	118° included angle Chisel Point.

Material Used On

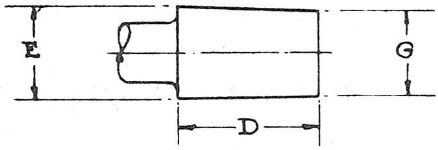
Fig. 1, Fig. 2, Fig. 3 Average Class of Work.
Fig. 4 Steel Rails 7% to 13% Manganese and Hard Material.
Fig. 5 Heat Treated Steels, Drop Forgings (Automobile Connecting Rods) Brinell Hardness 250.
Fig. 6 Cast Iron—Soft.
Fig. 7 Brass.
Fig. 8 Wood, Hard Rubber, Bakelite and Fiber (No. 6 may also be used).
Fig. 9 Copper.
Fig. 10 Crankshafts.

In up-to-date drilling practice drilling different grades of materials requires at times a modification of the commercial 118° drill point for maximum results.

Hard materials require a blunter point with the more acute angle for softer materials.

We have conducted exhaustive experiments with different angles of points in various grades of materials and are giving this information herewith in hopes that it will be of value to the consumers of drills. Also a list of speeds and feeds for drills used in various materials which were established on a production basis and which will be of value as a standard reference from which to deviate according to conditions. There are many variable factors involved in drilling operations, such as different materials, degrees of hardness, depth of holes, lack of uniformity of materials, lubrication, etc., which make it difficult to establish a list on speeds and feeds that will conform satisfactorily to all conditions.

FINISH DIMENSIONS OF JACOBS TAPERS FOR REFERENCE USE ONLY
SEE INDIVIDUAL DRAWINGS FOR COMPLETE DETAILS OF PLUG & RING GAGES

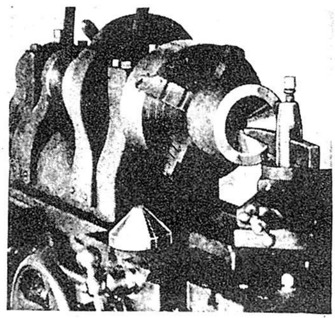


Jacobs Taper	E	G	D	Taper Per Foot	Ring Gage Dwg. No.	Plug Gage Dwg. No.	Model Number of Chuck Using The Taper
0	.2496	.228	.4375	.5914	B375	B366	0
1	.3846	.334	.6563	.9251	B376	B367	1A, 7-1A, 30-1A, 255, 42001, 250-1A, 40001, 42101
2	.5594	.488	.875	.9786	B377	B368	2A, 6A-2A, 5, 11, 11N, 32, 375, 381, 44002, 44102
2 Short	.5492	.488	.750	.9786	B378	B369	7, 8½N, 30, 250, 312, 318, 42002, 42102
3	.8109	.746	1.2188	.6390	B379	B370	3, 3A, 14N, 16N, 36, 75A, 100CR
4	1.1238	1.037	1.6563	.6289	B380	B371	18N
5	1.4129	1.316	1.875	.6201	B381	B372	20N
6	.6759	.624	1.000	.6229	B382	B373	6, 34, 500, 3A-6A, 44006, 44106
33	.6245	.561	1.000	.7619	B383	B374	6A-33, 33
VALVE REFACERS							
32VR	.6759	.624	1.000	.6229	B382	B373	32VR
34VR(S)	.7925	.746	.875	.6390	C2273	C2505	34 VR(S)
34VR(L)	.8860	.761	1.500	1.0000	C3145		34 VR(L)
3AVR	.8919	.842	.9380	.6390	C2503	C2506	3A VR
4AVR	1.1073	1.037	1.3430	.6289			4AVR
58VR	1.1249	1.000	1.500	1.0000	C2504	C2507	58VR - 75 VR
100VR	1.6851	1.482	2.4375	1.0000			100 VR

THE JACOBS MFG. CO.
Hartford, Conn., U.S.A.

Taper Turning with Compound Rest

The compound rest of the lathe is usually used for turning and boring short tapers and bevels, especially for bevel gear blanks and for die and pattern work, etc. The compound rest swivel is set at the required angle and the taper is machined by turning the compound rest feed screw by hand.



Machining a Conical **Punch** and Die with Compound Rest

MACHINING ALLEGHENY STAINLESS STEELS

The machining characteristics of Stainless Steels depend on composition, structural condition and hardness. High alloy content in stainless steel produces high tensile strength and great toughness. Stainless cannot be machined as rapidly as carbon steel or the lower alloy steels, it requires a suitable technique for each type of operation and for each different grade. The following outline is a guide for the development of such technique:

Chromium Nickel Alloys contain 16% to 26% chromium and 17% to 21% nickel, depending on the analysis type. These tend to work-harden very rapidly. For machining: maintain a continuous cut, at a relatively low speed, with a heavy cut and feed. (Type 303 is the only free-machining analysis in this group, it rates about 60% of screw stock machinability.

Straight Chromium Alloys contain 10% to 30% chromium. Type 416 and 430-F are the free-machining types in this grade, rate about 80% of screw stock machinability.

Cutting Tools: Use high speed steel or cemented carbide, depending on application. Straight carbon steel tools are not satisfactory. Keep cutting edges keen at all times. Honing of top surface is recommended. In grinding high speed tools for cutting and turning, make the side and end clearance approximately 8°, top rake of about 20°, and side rake about 4°.

Speeds and Feeds for Lathe, Shaper, Planer, Milling and Screw Machine: Because of work-hardening, especially the chromium nickel types, it is important to maintain a constant feed and not allow the tool to ride on the work. Take the heaviest practical cut, with the heaviest possible feed, with a corresponding reduction in surface speeds. The work and tools must be held rigid.

Lubricants: Where possible, lubricate all machining operations. Use any good grade of sulfur base oil or a good grade of lard oil with sulfur added (one pound per gallon makes a good lubricant). Water soluble cutting oils with sulfur added are sometimes satisfactory but use a heavier cutting compound than for ordinary alloys.

Threading and Tapping: Use high speed steel chasers and taps and have as many flutes as possible to provide the maximum number of cutting edges. The tools should be ground so that only 3 or 4 full threads are being cut at one time. Flood the tools with lubricant at all times.

Drilling: Don't work-harden the point of entry with heavy center punch blows. Lubricate plentifully—particularly on heavy work. Use high speed drills with keen cutting edges and good back clearance. Use drills with a heavy webb and a quick spiral ground slightly flatter than for ordinary work. Always keep drill cutting, because riding will work-harden the hole. **Drilling Through-Holes:** Back up the metal firmly with plates.

Sawing: Use high speed hack-saw blades with fine wavy teeth. Follow manufacturers' data. Don't let saw ride on work. Use same type coolant recommended above.

Important: Final machined finish directly effects corrosion resistance. A smooth polished surface resists corrosion much better than when rough or pitted. For chromium nickel alloys subject to *severe corrosion*, relieve the machining stresses by subsequent heat treatment. Clean the piece prior to heat treatment.

Castings: Straight chromium and chromium nickel alloys are machinable under the same conditions as apply to these alloys in wrought form. In machining castings, use heavy tools to offset the effects of vibration and dragging.

SUGGESTED SURFACE FEET PER MINUTE

For Turning and Threading Different Materials

NOTE: When steels are heat-treated, use lower figures in table

A.I.S.I. NUMBER	TURNING	THREADING
Sulphurized Carbon Steels		
B 1112	140-190	30-60
C 1113	180-250	40-80
C 1120	110-150	25-50
Non Sulphurized Carbon Steels		
C 1010	70-100	15-30
C 1015	70-100	15-30
C 1020	100-130	20-40
C 1030	100-130	20-40
C 1040	85-115	15-35
C 1050	75-105	15-35
Manganese Steels		
A 1320	75-105	15-35
A 1330	75-105	15-35
A 1335	75-105	15-35
A 1340	70-100	15-30
Nickel Steels		
A 2317	85-115	20-35
A 2330	70-100	15-30
A 2340	70-100	15-30
A 2515	55- 75	10-20
Nickel Chromium Steels		
A 3045	85-115	20-35
A 3120	85-115	20-35
A 3130	75-105	15-35
A 3140	70-100	15-30
A 3240	70-100	15-30
E 3310	65- 85	15-25
Molybdenum Steels		
A 4023	105-145	25-45
A 4032	100-130	20-40
A 4042	95-125	20-40
A 4047	85-115	20-35
Chromium Molybdenum Steels		
A 4119	100-130	20-40
A 4130	100-130	20-40
A 4137	95-125	20-40
A 4145	85-115	20-35
A 4150	75-105	15-35
Nickel Chromium Molybdenum Steel		
A 4320	75-105	15-35
A 4340	70-100	15-30
Nickel Molybdenum Steel		
A 4615	95-125	20-40
A 4640	75-105	15-35
A 4815	70-100	15-30

A.I.S.I. NUMBER	TURNING	THREADING
Chromium Steels		
A 5045	95-125	20-40
A 5120	100-130	20-40
A 5140	95-125	20-40
A 5150	80-115	20-35
Chromium High Carbon Steel		
E 52100	40-60	10-20
Chromium Vanadium Steels		
A 6120	75-105	15-35
A 6145	75-105	15-35
A 6152	70-100	15-30

NE NUMBER	TURNING	THREADING
Manganese Molybdenum Steels		
NE 8024	85-115	20-35
NE 8124	75-105	15-35
NE 8233	85-115	20-35
NE 8339	85-115	20-35
NE 8442	65- 85	15-25
Nickel Chromium Molybdenum Steel		
NE 8620	85-115	20-35
NE 8720	100-130	20-40
NE 8949	70-100	15-30
Manganese Silicon		
NE 9260	70-100	15-30
Manganese Silicon Nickel Chromium Molybdenum Steel		
NE 9420	85-115	20-35
NE 9440	70-100	15-30
NE 9537	70-100	15-30
NE 9550	65- 85	15-25
Manganese Silicon Chromium Steel		
NE 9630	70-100	15-30
NE 9650	65- 85	15-25

A = Basic Open Hearth Alloy Steels
B = Acid Bessemer Carbon Steels
C = Basic Open Hearth Carbon Steels
E = Electric Furnace of both carbon & alloy
NE = National Emergency Steels

Stainless Steels

	TURNING	THREADING
Type 416 (14 Chrome) F.M.	95-125	15-35
Type 430 (14 Chrome) F.M.	95-125	15-35
Type 303 (18-8) F.M.	55-75	10-20

Other Materials

	TURNING	THREADING
Monel	65-85	15-25
Nickel Silver	65-85	15-25
Nickel Silver Leaded	110-150	25-50
Tool Steels	25-50	5-10
Steel Tubing	95-125	20-40
Cast Iron	100-130	20-40

	TURNING	THREADING
Malleable Iron	105-145	20-45
Brass Rod	Any Speed	Any Speed
Cast Brass	Any Speed	Any Speed
Naval Brass	55-75	10-20
Bronze Lead Bearing	300-400	30-60
Bronze Manganese	55-75	10-20
Copper	95-125	20-40
Aluminum	100 up	20 up
Magnesium Alloy	100 up	20 up
Fibre	Any speed	Any speed
Rubber	Any speed	Any speed
Plastic	Any speed	Any speed

Grinding in the Lathe

When equipped with a good electric grinding attachment the lathe can be used for sharpening reamers and milling cutters, grinding hardened bushings and shafts and many other grinding operations.

The V-ways of the lathe bed should be covered with a heavy cloth or canvas to protect them from dust and grit from the grinding wheel, and the lathe spindle bearings should also be protected. A small pan of water or oil placed just below the grinding wheel will collect most of the grit.

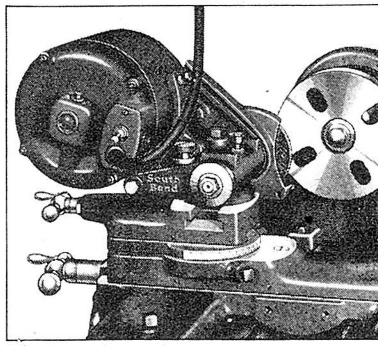


Fig. 1 External Grinding Attachment for the Lathe

A large, powerful grinder is most satisfactory for external grinding. The wheel should be at least four inches in diameter and the grinder should be mounted direct on the compound rest of the lathe, as shown in Fig. 1.

A small high speed grinder is best for internal grinding, as speed is more important than power for this class of work.

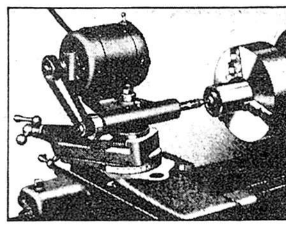


Fig. 2. Internal Grinding Attachment for Lathe

Grinding Wheel Speeds

The tabulation below shows grinding wheel speeds in revolutions per minute for surface speeds of 4000 and 5000 feet per minute.

Diam. Wheel	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	10 in.	12 in.
R.P.M. for surface Speed of 4,000 ft.	15,279	7,639	5,093	3,820	3,056	2,546	2,183	1,910	1,529	1,273
R.P.M. for surface Speed of 5,000 ft.	19,099	9,549	6,366	4,775	3,820	3,183	2,728	2,387	1,910	1,592

GRINDING WHEELS FOR VARIOUS KINDS OF WORK

Tabulation shows grade of Norton Grinding wheels.

Kind of Work	Rough Grind	Finish Grind
Cast Iron	3736-K Crystolon	3760-J Crystolon
Soft Steel	46-M5BE	60-M5BE
Hardened Steel	3846-L5BE	3860-L5BE
High Speed Steel	3846-K5BE	3860-K5BE
Brass or Bronze	3736-K Crystolon	3760-J Crystolon
General Work	46-N5BE	46-N5BE
Aluminum	30-M3L Shellac	36-M3L Shellac
Bakelite	3736-K Crystolon	3746-K Crystolon
Soft Rubber	3720-K5T-2 Crystolon Bakelite	3746-K5T-2 Crystolon Bakelite
Hard Rubber	3730-K5T-2 Crystolon Bakelite	3760-K5T-2 Crystolon Bakelite
Automobile Valves	1960-M	80-L6BE
Tungsten Carbide	3760/1-17 Crystolon	37100/2-H7 Crystolon

Winding Coils in the Lathe

The unusually wide range of positive power longitudinal feeds available on the lathe make it an ideal machine for winding electrical coils of all kinds. A revolution counter may be attached to register the number of turns, as shown in Fig. 1 Special gearing may be obtained for odd leads not in the usual thread cutting range of the lathe. Any type of coil form or wire guide required may be used.

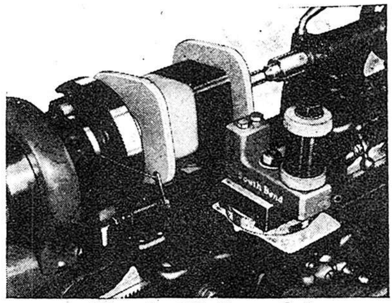


Fig. 1 Winding a Coil

Spring Winding

Coil springs of all kinds may be wound on the lathe, as shown in **Fig. 2** Special mandrels are used for irregular shaped springs. The lead screw and half nuts of the lathe are usually used to obtain a uniform lead so that the coils are all equally spaced.

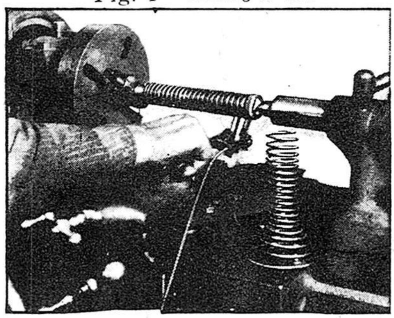


Fig. 2 Winding a Spring

Boring Work Mounted on Lathe Carriage

Large work may be mounted on the lathe carriage for boring, as shown in **Fig. 5**.

The boring bar is held between centers and driven by a lathe dog. The work is clamped to the top of the lathe saddle and is fed to the tool by the automatic longitudinal feed of the carriage.

Several good types of boring bars for this class of work are shown in Figs. 3 4 and 6

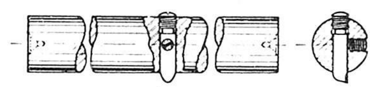


Fig. 3 Boring Bar with Fly Cutter

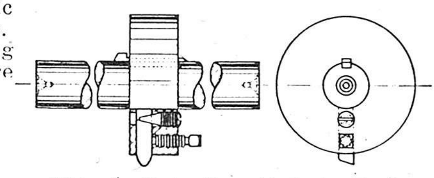


Fig. 4. Boring Bar with Boring Head

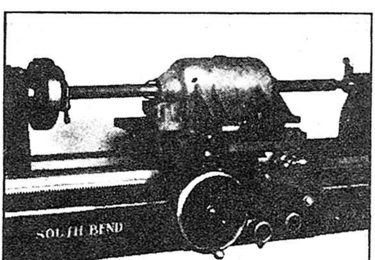


Fig. 5 Boring on the Lathe Carriage

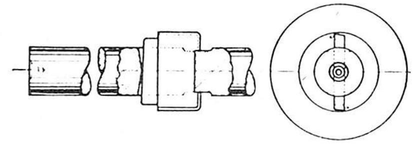


Fig. 6 Boring Bar for Sizing the Hole

Filing and Polishing

All tool marks can be removed and a smooth, bright finish obtained on the surface of a piece of work by filing and polishing, as shown in Figs. 1 and 2

Use a fine mill file and file with the lathe running at a speed so that the work will make two or three revolutions for each stroke of the file. File just enough to obtain a smooth surface. If too much filing is done the work will be uneven and inaccurate.

Keep the left elbow high and the sleeves rolled up so there will be no danger from the lathe dog.

Keep the file clean and free from chips, using a file card frequently.

A very smooth, bright finish may be obtained by polishing with several grades of emery cloth after filing. Use oil on the emery cloth and run the lathe at high speed. Be careful not to let the emery cloth wrap around the revolving work.

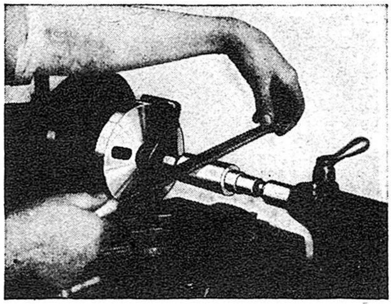


Fig. 1. Filing to Remove Tool Marks

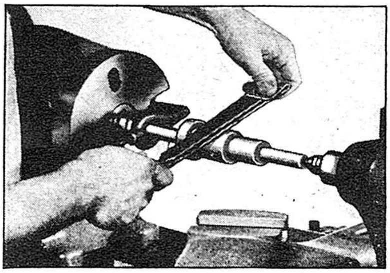


Fig. 2 Polishing with Emery Cloth and Oil

Lapping

Hardened gauges, bushings and bearings are often finished in the lathe by lapping, as shown in Fig. 3 Emery cloth, emery dust and oil, diamond dust and other abrasives are used. Usually the lathe spindle is operated at high speed.

The lap may be very simple, consisting of a strip of emery cloth attached to a shaft, or it may be elaborately constructed of lead, copper, cast iron, etc. Some very fine and precise work may be accomplished by careful lapping.

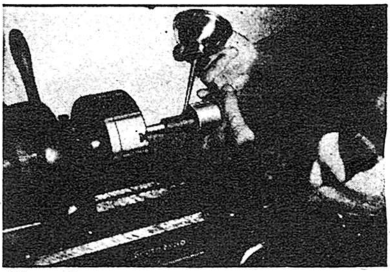


Fig. 3 Lapping the Inside of a Hardened Steel Bushing with Emery Dust and Oil

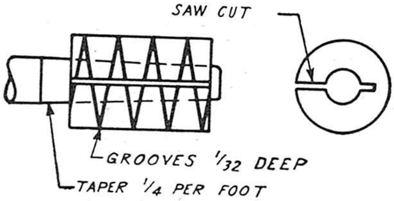
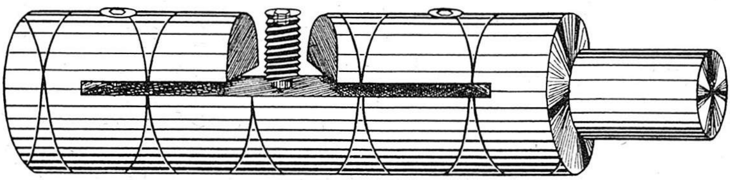


Fig. 4 A Cast Iron Lap for Emery Dust

Continued on next page

A good serviceable lap for general use is illustrated on this page. The construction of such a lap is simple. Turn the cast-iron piece all over to rough size—turn handle end to size—turn lap surface to standard size minus one thousandth of an inch or two thousandths if the holes you lap are apt to come that small. With work turning at a slow spindle speed, turn slight line in lap surface at very coarse lead about one inch per revolution. This feed can be done by hand as there is nothing particular about it. Make two such cuts, one right-hand lead, the other left hand. The purpose of these grooves is simply to act as grit and oil distributor troughs. They should be about $\frac{1}{64}''$ to $\frac{1}{32}''$ wide and $\frac{1}{64}''$ to $\frac{1}{32}''$ deep, depending on diameter of the lap. Cut with a sharp vee tool.



The lap surface is next split with a milling cutter within about $\frac{1}{4}''$ to $\frac{3}{8}''$ from the end of the lapped surface as shown above. It is then drilled and tapped at right angles to the split for the expansion screws. This slit through lap permits expansion by means of set screws in one-half acting on other half through the slot as shown.

The best grits to employ are Arkansas grit, of the correct grain for the work to be tapped, and Bon Ami cleaning powder. These grits are not as fast cutting as some but produce good accurate work with a high finish. The grit used is mixed with machine oil to a light paste consistency and applied to the lap evenly.

The lap is then pushed into the hole with a combination push and twist drill going in and pull and twist in opposite direction coming out. The lap is rotated slightly in the hole after every complete stroke to avoid lapping too much in a position which might keep the hole from being lapped cylindrically round.

Sufficient take-up should always be given to the adjusting screw to insure the lap fitting the hole snugly. If this is not done the hole may be lapped bell mouthed.

The above-mentioned grits and procedure may be used when lapping holes in steel, either hard or soft, cast iron and bronze, and are advantageous in that the work is not charged with the cutting grit as may occur when emery or carborundum is employed.

LATHE TOOL SHARPENING

The angle of the cutter bit with the bottom of the tool holder must be taken into consideration when grinding cutter bits.

The side clearance Fig. 1. is to permit the cutting edge to auvance freely without the heel of the tool rubbing against the work.

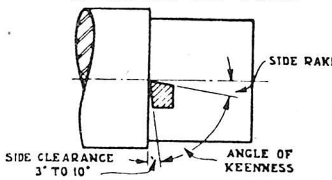


Fig. 1.

Correct Side Clearance and Side Rake of Cutter Bit

The front clearance Fig. 2 is to permit the cutting edge to cut freely as the tool is fed to the work.

Too much clearance will weaken the cutting edge so that it will break; but insufficient clearance will prevent the tool from cutting.

Side rake and back rake (Figs. 1 and 2 also facilitate free cutting. For cast iron, hard bronze and hard steel, very little side rake or back rake are required.

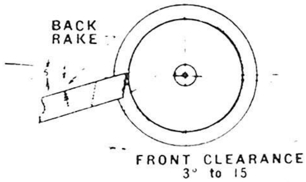
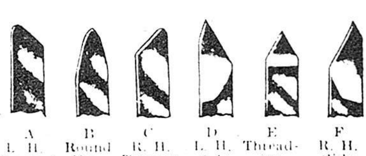


Fig. 2. Correct Front Clearance and Back Rake of Cutter Bit

Cutter Bit After Grinding



Set of Ground Cutter Bits

The angle of keenness Fig. 1 may vary from 60° for soft steel to nearly 90° for cast iron, hard steel, bronze, etc.

Figs. 3 to 4 inclusive, show the various steps in grinding a cutter bit for general machine work. Honing the cutting edge (Fig. 8 will improve the quality of the finish and lengthen the life of the tool.

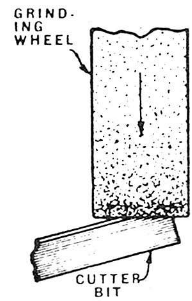


Fig. 3. Grinding Left Side of Cutter Bit

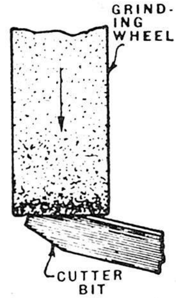


Fig. 4. Grinding Right Side of Cutter Bit

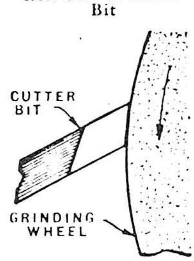


Fig. 5. Grinding Front of Cutter Bit

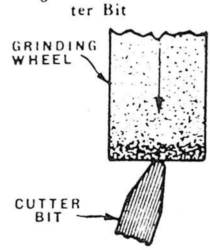


Fig. 6. Rounding End of Cutter Bit

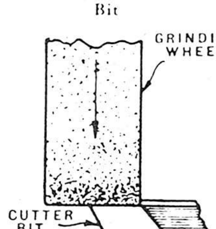


Fig. 7. Grinding Side Rake and Back Rake

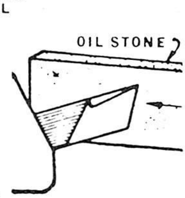


Fig. 8. Honing the Cutting Edge of Cutter Bit with an Oil Stone

Unground Cutter Bit

LATHE TOOLS

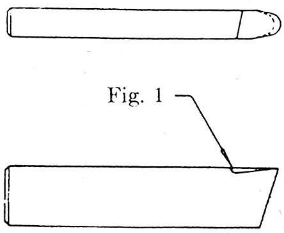


Fig. 1

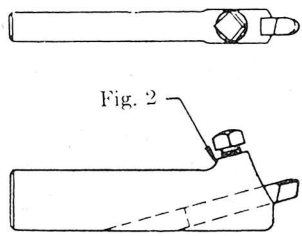


Fig. 2

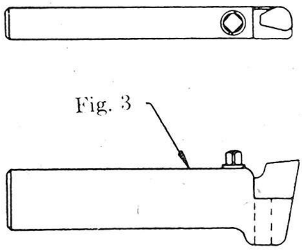


Fig. 3

Each lathe should be equipped with a complete set of lathe tools for turning, facing, threading and boring. They can be either of the forged type (1), or of the tool holder type using high-speed steel bits, such as are made by Williams, Armstrong (2) or O. K. (3). The tool holder type is the most commonly used because it is more convenient. No forging or dressing is necessary with this type.

A complete set of tools consists of the following:

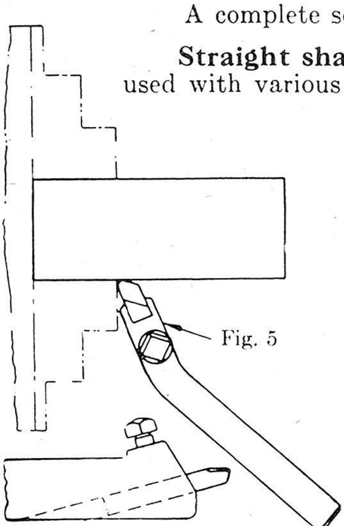


Fig. 5

Straight shank turning tool (4), which can be used with various types of tool bits for right and left-hand turning, right and left-hand facing, and threading. Bits can also be ground to special shapes for fillets in corners, etc.

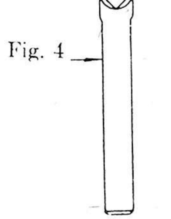


Fig. 4

Left-hand offset turning tools (5) are desirable when the operator wishes to work close to the chuck or the driving dog. By using this type of tool it is possible to turn the

Continued on next page

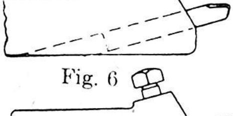


Fig. 6

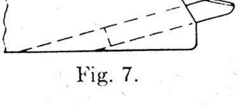


Fig. 7.

For turning brass, there should be no top rake (6) and the cutting edge of the tool should be about horizontal. For turning soft copper, babbitt, and some die casting alloys, a negative rake (7) is often used.

piece up to the chuck and at the same time have the chuck clear the side of the carriage and compound rest.

Right-hand offset turning tools (8) answer the same purpose when working at the tailstock end. Various shaped bits can be used in either right or left-hand turning tool holders to suit the work being done.

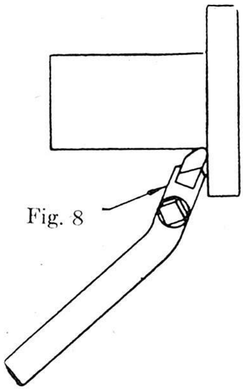


Fig. 8

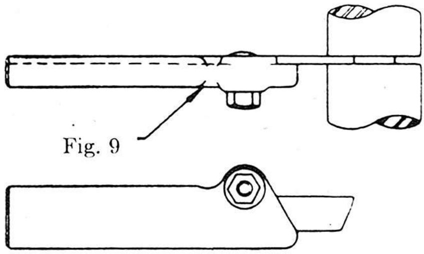


Fig. 9

Straight cutting-off tools (9) are used for cutting off in the lathe. The blade used in this tool is ground with the proper side clearance. Then, when properly set in the holder, the tool does not drag.

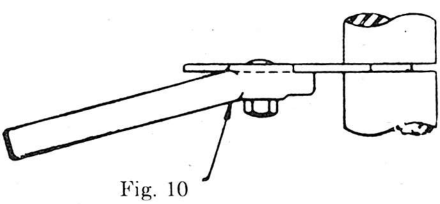


Fig. 10

The right-hand cutting-off tool (10) is used for cutting off work close to the chuck. To prevent chatter, when using a tool of this type, excessive overhang of the work should be avoided.

The left-hand cutting-off tool (11) is for use near the tailstock end of the lathe. This type of tool is rarely used and in most cases the right-hand cutting-off tool serves all purposes.

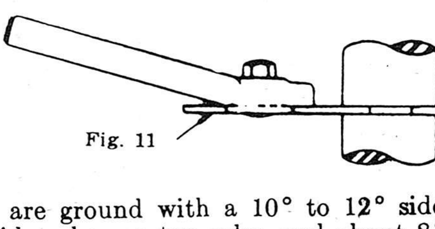


Fig. 11

Steel finishing side tools are ground with a 10° to 12° side clearance, about 10° to 15° side rake, no top rake, and about 8° front clearance.

Cast iron, brass, etc., the same clearance except no side rake is used on tool.

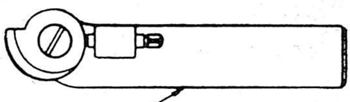


Fig .12

Threading or chasing tools (12). There are many patented types of threading tools. The tool shown is provided with a formed cutter, and is ground on the top to maintain the correct thread form. On some classes of material where it is not possible to cut a smooth thread with a rigid chasing tool, a spring threading tool (13) will produce better results.

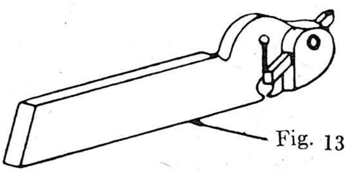


Fig. 13

The spring threading tool is built with a nut for the lockable spring head which provides rigid backing for coarse threads and heavy cuts, and when loosened, the holder becomes a spring tool for finishing work. Neither of these tools is absolutely essential as most threads can be cut by grinding a tool bit to the proper shape, with the use of a thread gauge. The bit is held in a turning tool holder.

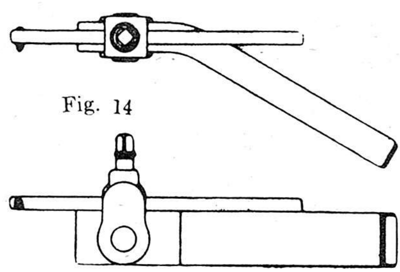


Fig. 14

Boring bars and holders. Tools of the type shown are used for boring holes and chasing internal threads. Two basic types of boring bars are used, namely, the forged type and the bar and holder type. Three of the bar and holder types are shown in the accompanying illustrations. No. 14 is used for small holes, which in addition to holding bars with bits as shown, can be used to hold boring tools made of drill rod for very small holes, and also for holding drills for drilling. The boring bar shown in illustration (15) is used for medium size holes and is adjustable for different depths of holes. It is held in the regular tool post by a shank, the same as the turning tool.

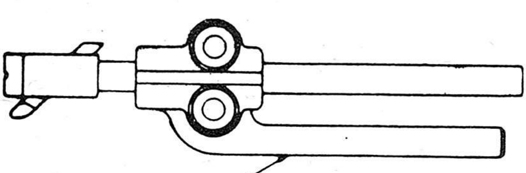


Fig. 15

A tool properly ground should have the point set on the center line of the work. Some operators make a practice of setting the tool above the center line, about $\frac{1}{64}$ of an inch for each 1″ clearance in diameter. This, however, necessitates changing the clearance and rake angles of the tool and for this reason we do not recommend it for the student or beginner.

Figure (16) shows a boring bar for heavy work that is held in the compound rest T-slot. This makes the bar more rigid than when held in the tool post. Various shaped tool bits for boring, facing, counterboring and threading holes can be used in the different bars.

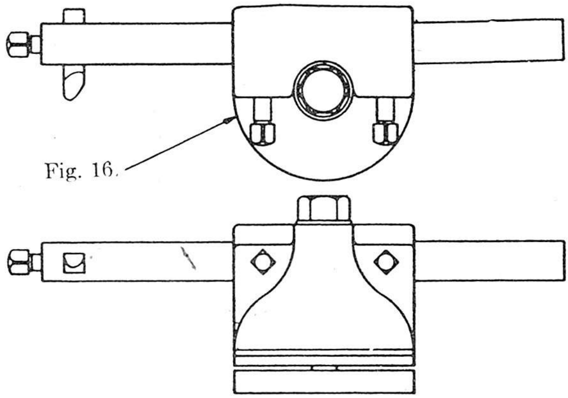


Fig. 16.

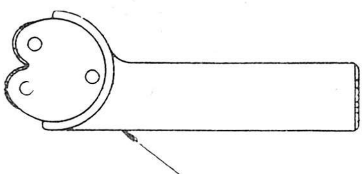
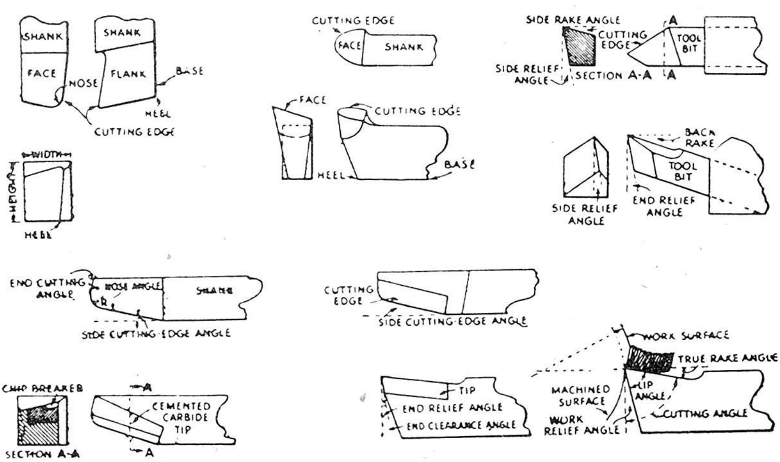


Fig. 17

Knurling tool (17). On some classes of work such as thumb screws, it is necessary to roughen the diameter to give a better grip and prevent oily fingers from slipping. This is called knurling and is used extensively on optical, radio and other electrical work. A tool holder carrying two knurled wheels is fed into the work while it is revolving and impresses a pattern on the work. Wheels of different patterns can be obtained for the knurling tool holder.

Nomenclature of Lathe Tools



On work to be finish ground, make the finish turned diameter 15 thousandths over actual finish ground diameter.

On work to be file finished and polished, leave 2 to 3 thousandths of an inch over finish size to provide stock to file and remove slight tool marks and give polish finish.

ENGINEERING INFORMATION COVERING THE DESIGN AND APPLICATION OF SPUR GEARS

To Say 3 P. or 3 Pitch Means 3 Diametral Pitch
To Say 3″ P. or 3 inch Pitch Means 3 inch Circular Pitch

The word *"diameter"* when applied to gears is always understood to mean the pitch diameter.

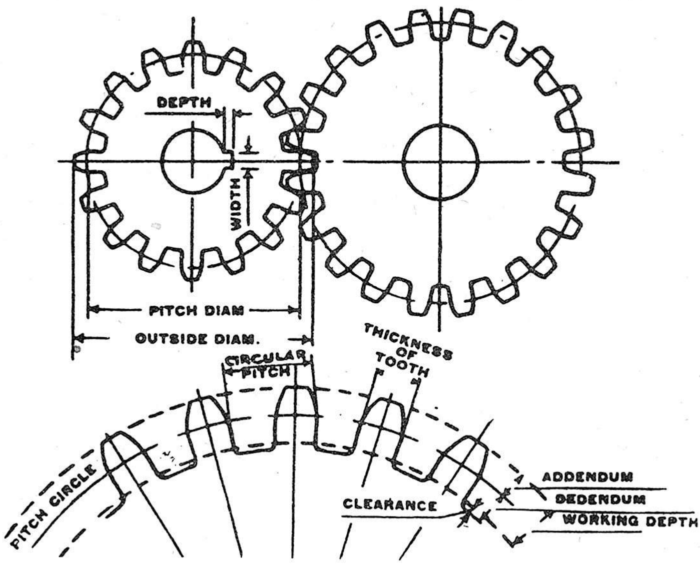
Diametral pitch of the gear is the number of teeth to each inch of its pitch diameter.

Circular pitch is the distance from the center of one tooth to the center of the next tooth, measured along the pitch circle.

Addendum is the distance measured from pitch circle to the outside or circumference of the gear.

Dedendum is the distance measured from the pitch circle to the bottom of the tooth.

Clearance is equivalent to 1.57 divided by the diametral pitch, or about 1/16 of the depth of tooth.



RULES AND FORMULAE FOR INTERNAL SPUR GEARS

(Where rules and formulas are not given, they are the same as for external gears)

To Find	Rule	Formula
Center Distance	Subtract the number of teeth in the pinion from the number of teeth in the gear and divide the remainder by 2 times the diametral pitch.	$C = \frac{N_g - N_p}{2P}$
Center Distance	Multiply the difference of the numbers of teeth in the gear and pinion by the circular pitch and divide the product by 6.2832.	$C = \frac{(N_g - N_p)\ P'}{6.2832}$

(Continued on top of next page.)

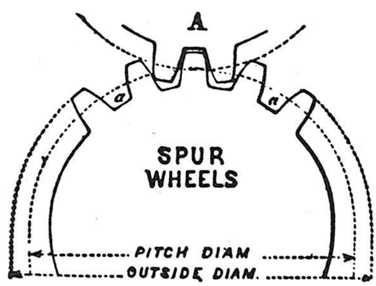
Inside Diameter	Subtract 2 from the number of teeth and divide the remainder by the diametral pitch.	$I = \frac{N-2}{P}$
Inside Diameter	Subtract 2 from the number of teeth, multiply the remainder by the circular pitch, and divide the product by 3.1416.	$I = \frac{(N-2)\,P'}{3.1416}$
Pitch Diameter	Add twice the addendum to the inside diameter.	$D = I + 2S$
Inside Diameter	Subtract twice the addendum from the pitch diameter.	$I = D - 2S$

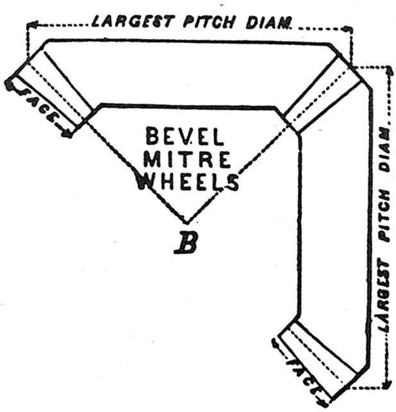
RULES AND FORMULAE FOR DIMENSIONS OF SPUR GEARS

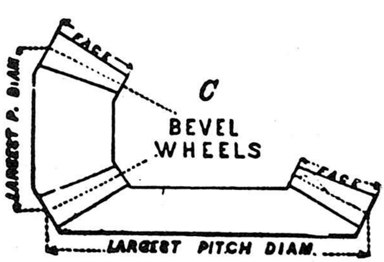
No. of Rule	To Find	Rule	Formula
1	Diametral Pitch	Divide 3.1416 by circular pitch.	$P = \frac{3.1416}{P'}$
2	Circular Pitch	Divide 3.1416 by diametral pitch.	$P' = \frac{3.1416}{P}$
3	Pitch Diameter	Divide number of teeth by diametral pitch.	$D = \frac{N}{P}$
4	Pitch Diameter	Multiply number of teeth by circular pitch and divide the product by 3.1416.	$D = \frac{NP'}{3.1416}$
5	Center Distance	Add the number of teeth in both gears and divide the sum by two times the diametral pitch.	$C = \frac{N_g + N_p}{2P}$
6	Center Distance	Multiply the sum of the number of teeth in both gears by circular pitch and divide the product by 6.2832.	$C = \frac{(N_g + N_p)P'}{6.2832}$
7	Addendum	Divide I by diametral pitch.	$S = \frac{I}{P}$
8	Addendum	Divide circular pitch by 3.1416.	$S = \frac{P'}{3.1416}$
9	Clearance	Divide 0.157 by diametral pitch.	$F = \frac{0.157}{P}$
10	Clearance	Divide circular pitch by 20.	$F = \frac{P'}{20}$
11	Whole Depth of Tooth	Divide 2.157 by diametral pitch.	$W = \frac{2.157}{P}$
12	Whole Depth of Tooth	Multiply 0.6866 by circular pitch.	$W = 0.6866\,P'$
13	Thickness of Tooth	Divide 1.5708 by diametral pitch.	$T = \frac{1.5708}{P}$
14	Thickness of Tooth	Divide circular pitch by 2.	$T = \frac{P'}{2}$
15	Outside Diameter	Add 2 to the number of teeth and divide the sum by diametral pitch.	$O = \frac{N+2}{P}$
16	Outside Diameter	Multiply the sum of the number of teeth plus 2 by circular pitch and divide the product by 3.1416.	$O = \frac{(N+2)\,P'}{3.1416}$
17	Diametral Pitch	Divide number of teeth by pitch diameter.	$P = \frac{N}{D}$
18	Circular Pitch	Multiply pitch diameter by 3.1416 and divide by number of teeth.	$P' = \frac{3.1416\,D}{N}$
19	Pitch Diameter	Subtract two times the addendum from outside diameter.	$D = O - 2S$
20	Number of Teeth	Multiply pitch diameter by diametral pitch.	$N = P \times D$
21	Number of Teeth	Multiply pitch diameter by 3.1416 and divide the product by circular pitch.	$N = \frac{3.1416\,D}{P'}$
22	Outside Diameter	Add two times the addendum to the pitch diameter.	$O = D + 2S$
23	Length of Rack	Multiply number of teeth in rack by 3.1416 and divide by diametral pitch.	$L = \frac{3.1416\,N}{P}$
24	Length of Rack	Multiply the number of teeth in the rack by circular pitch.	$L = NP'$

BEVEL GEARS

The curve of teeth in bevel gears, when correctly formed, changes constantly from one end of the tooth to the other. Therefore bevel gears, whose teeth are produced with a cutter of fixed curve, are not theoretically correct, the cutter usually being of a curve that will make the correct form at the outer part of the face of the gear, and of necessity will leave the curves too large at the inside ends of the teeth.







Small bevel gearing is almost universally produced in this manner, which practically answers the purpose, except when the teeth are very coarse or the gears very small, in which cases their operation is not satisfactory.

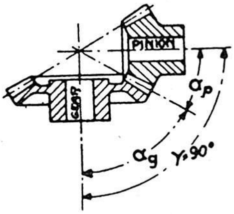
In place of cutting by changing position of cutter, etc., the teeth are often filed slightly, in order to round them off to the curve required for their free running.

On all bevel gears cut with a cutter of fixed curve, it is necessary to cut through twice owing to the necessity of making the thickness of the cutter on the pitch line equal to about .005" thinner than the space between the teeth at the smallest pitch diameter. As the width of space between the teeth on the largest pitch diameter should be greater than the thickness of the cutter, it must be made so by passing the cutter through a second time.

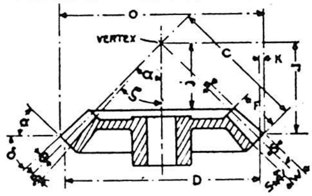
The cuts on this page will explain the forms of spur, bevel and mitre gears, also the terms "pitch diameter," "outside diameter," "largest pitch diameter," "length of face," etc

When a pair of bevel gears are of same size and number of teeth, with their lines of centres at right angles, they are called "mitre gears," and one cutter will answer for both; but where one gear has a greater number of teeth, or differs in bevel from the one running into it, then each of the pair of gears may require a different cutter.

RULES AND FORMULAS FOR CALCULATING BEVEL GEARS WITH SHAFTS AT RIGHT ANGLES



a_p = Pitch cone angle of pinion;
a = Pitch cone angle of gear;
N_p = Number of teeth in pinion, etc.



No.	To Find	Rule	Formula
1	Pitch Cone Angle (or Edge Angle) of Pinion.	Divide the number of teeth in the pinion by the number of teeth in the gear to get the tangent.	$\tan a_p = \frac{N_p}{N_g}$
2	Pitch Cone Angle (or Edge Angle) of Gear.	Divide the number of teeth in the gear by the number of teeth in the pinion to get the tangent.	$\tan a_g = \frac{N_g}{N_p}$
3	Proof of Calculations for Pitch Cone Angles	The sum of the pitch cone angles of the pinion and gear equals 90 degrees.	$a_p + a_g = 90°$
4	Pitch Diameter.	Divide the number of teeth by the diametral pitch; or multiply the number of teeth by the circular pitch and divide by 3.1416.	$D = \frac{N}{P} = \frac{NP'}{\pi}$
5	Addendum.	Divide 1.0 by the diametral pitch; or multiply the circular pitch by 0.318.	$S = \frac{1.0}{P} = 0.318\ P'$
6	Dedendum.	Divide 1.157 by the diametral pitch; or multiply the circular pitch by 0.368.	$S + A = \frac{1.157}{P} = 0.368\ P'$
7	Whole Depth of Tooth Space.	Divide 2.157 by the diametral pitch; or multiply the circular pitch by 0.687.	$W = \frac{2.157}{P} = 0.687\ P'$
8	Thickness of Tooth at Pitch Line.	Divide 1.571 by the diametral pitch; or divide the circular pitch by 2.	$T = \frac{1.571}{P} = \frac{P'}{2}$
9	Pitch Cone Radius.	Divide the pitch diameter by twice the sine of the pitch cone angle.	$C = \frac{D}{2 \times \sin a}$
10	Addendum of Small End of Tooth.	Subtract the width of face from the pitch cone radius, divide the remainder by the pitch cone radius and multiply by the addendum.	$s = S \times \frac{C - F}{C}$
11	Thickness of Tooth at Pitch Line at Small End.	Subtract the width of face from the pitch cone radius, divide the remainder by the pitch cone radius and multiply by the thickness of the tooth at the pitch line.	$t = T \times \frac{C - F}{C}$
12	Addendum Angle.	Divide the addendum by the pitch cone radius to get the tangent.	$\tan \theta = \frac{S}{C}$
13	Dedendum Angle.	Divide the dedendum by the pitch cone radius to get the tangent.	$\tan \Phi = \frac{S + A}{C}$
14	Face Angle.	Subtract the sum of the pitch cone and addendum angles from 90 degrees.	$\delta = 90° - (a + \theta)$
15	Cutting Angle.	Subtract the dedendum angle from the pitch cone angle.	$\zeta = a - \Phi$
16	Angular Addendum.	Multiply the addendum by the cosine of the pitch cone angle.	$K = S \times \cos a$
17	Outside Diameter.	Add twice the angular addendum to the pitch diameter.	$O = D + 2K$
18	Apex Distance.	Multiply one-half the outside diameter by the tangent of the face angle.	$J = \frac{O}{2} \times \tan \delta$

(Continued on top of next page)

19	Apex Distance at Small End of Tooth.	Subtract the width of face from the pitch cone radius; divide the remainder by the pitch cone radius and multiply by the apex distance.	$j = J \times \frac{C - F}{C}$
20	Number of Teeth for which to Select Cutter.	Divide the number of teeth by the cosine of the pitch cone angle.	$N' = \frac{N}{\cos a}$
21	Proof of Calculations by Rules Nos. 9, 12, 14, 16 and 17.	The outside diameter equals twice the pitch cone radius multiplied by the cosine of the face angle and divided by the cosine of the addendum angle.	$O = \frac{2C \times \cos 6}{\cos 0}$

RECOMMENDED PRACTICE FOR BEVEL GEARING

The American Gear Manufacturers Assn. has adopted as recommended practice the following rules:

The maximum length of face of bevel gears should not be over 1/3 of the cone distance for gears up to 3 in. pitch diameter and not over 1/4 of the cone distance for gears from 3 to 20 inch pitch diameter, assuming that the pitch in every case will be in proper proportion to the size of the gears. A safe rule is to make the face from 1½ to 2½ times the circular pitch.

The minimum length of bearing along the face is to be at least ½ the length of the face when the gears are held in correct alignment.

Bevel gears with generated involute teeth of standard addendum having a pressure angle of 14½° may be used according to the following rule:

RATIO	No. OF TEETH
1 to 1	14 and over
1½ to 1	18 and over
2 to 1	19 and over
3 to 1 and over	21 and over

This rule is given applying mainly to gears up to 20 inches pitch diameter and to average industrial machine design as distinguished from automobiles.

RECOMMENDED PRACTICE FOR BACKING DIMENSIONS OF BEVEL AND MITRE GEARS

The following formulae are recommended for the calculation of backing dimensions of Bevel and Mitre Gears.

BEVEL GEARS AND PINIONS

Backing in inches of Pinion $= \frac{\text{Pitch diameter of gear} \times .250}{(\text{Ratio of Gear to Pinion}) + 1}$

Backing in inches of Gear = (Pitch diameter of gear × .250) — Backing of Pinion

MITRE GEARS

Backing in inches of Gear = Pitch diameter × .125

This does not allow for set screws in pinions below 4 inches Pitch Diameter.

RULES FOR CALCULATING SPIRAL GEARS

The following rules are used for calculating the dimensions of spiral or helical gears:

Rule 1. The sum of the tooth angles of a pair of mating helical gears is equal to the shaft angle.

Rule 2. To find the pitch diameter of a helical gear, divide the number of teeth by the product of the normal pitch and the cosine of the tooth angle.

Rule 3. To find the center distance, add together the pitch diameters of the two gears and divide by 2. This rule is evidently the same as for spur gears.

Rule 4. To prove the calculations for pitch diameters and center distance, multiply the number of teeth in the first gear by the tangent of the tooth angle of that gear, and add the number of teeth in the second gear to the product; the sum should equal twice the product of the center distance multiplied by the normal diametral pitch, multiplied by the sine of the tooth angle of the first gear.

Rule 5. To find the number of teeth for which to select the cutter, divide the number of teeth in the gear by the cube of the cosine of the tooth angle.

Rule 6. To find the lead of the tooth helix, multiply the pitch diameter by 3.1416 times the cotangent of the tooth angle. The rules relating to the addendum and the whole depth of tooth are the same as for spur gears.

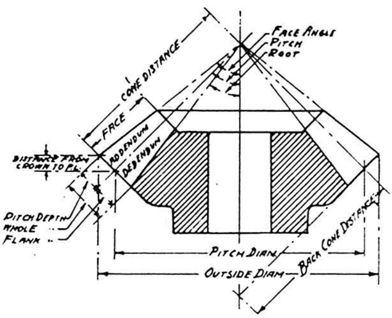
Rule 7. To find the addendum, divide 1 by the normal diametral pitch.

Rule 8. To find the whole depth of tooth space, divide 2.157 by the normal diametral pitch.

Rule 9. To find the normal tooth thickness at the pitch line, divide 1.571 by the normal diametral pitch.

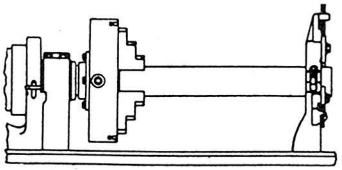
Rule 10. To find the outside diameter, add twice the addendum to the pitch diameter.

Rule 11. To find the equivalent diameter of a helical gear, divide the number of teeth of the gear by the diametral pitch of the cutter by which it is cut.

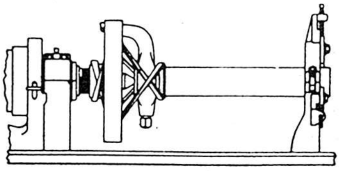


Rules for Figuring Bevel Gears

To Find	Rule
Pitch Diameter	$\frac{\text{Number of teeth}}{\text{Diametral Pitch}}$ or $\frac{\text{No. of teeth} \times \text{circular pitch}}{3.1416}$ or, No. of teeth $\times$ circ. pitch $\times$ .3183″
Pitch Depth	$\frac{1}{\text{Diametral Pitch}}$ or Circular Pitch $\times$ .3183″
Full Depth	(Standard) Pitch Depth $\times$ 2 + Circular pitch $\times$ .05 (Special)
Ratio	$\frac{\text{Number of teeth in Gear}}{\text{Number of teeth in Pinion}}$
Diameter Increment	(Pitch Depth $\times$ 2) $\times$ cosine of Pitch Angle.
Outside Diameter	Pitch Diameter + Diameter Increment
Tangent Pitch Angle Gear	$\frac{\text{Number of teeth in Gear}}{\text{Number of teeth in Pinion}}$
Tangent Pitch Angle Pinion	$\frac{\text{Number of teeth in Pinion}}{\text{Number of teeth in Gear}}$ or, 90°—Pitch Angle of Gear
Cone distance at Pitch Line	$\frac{\text{Pitch Radius of Gear}}{\text{Sine of Pitch Angle of Gear}}$
Back Cone distance	Cone distance $\times$ tangent Pitch Angle
Tangent of Addendum Angle	$\frac{\text{Pitch Depth}}{\text{Cone Distance}}$
Tangent of Block or Dedendum Angle.	$\frac{\text{Flank Depth}}{\text{Cone Distance}}$
Face Angle	Pitch Angle + Addendum Angle
Root Angle	Pitch Angle — Dedendum Angle
Distance from Crown to Pitch Line	Pitch Depth $\times$ Sine Pitch Angle
Pitch at Inside	Pitch at outside is to Pitch at inside as Cone distance is to (Cone distance) — face
Tooth Angle Tangent	$\frac{(\frac{1}{2}\text{ thickness of tooth at Pitch Line} + \text{flank depth} \times \text{tangent pressure angle})}{\text{cone distance}}$



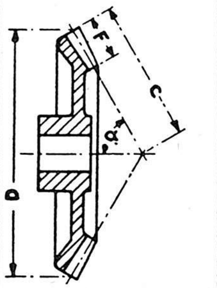
Work Mounted in Chuck and Center Rest



Work Mounted on Center and in Center Rest

FACTORS FOR CALCULATING STRENGTH OF BEVEL GEARS

These Y Factors are for Diametral Pitch. To obtain Circular Pitch Y Factors divide by 3.1416.



$N' = \dfrac{\text{Number of teeth}}{\cos a}$

Table of Outline Factors (Y) for 14½° and 20° Involute

N'	Outline Factor = Y: 14½° Involute (Std.)	Outline Factor = Y: 20° Involute	N'	Outline Factor = Y: 14½° Involute (Std.)	Outline Factor = Y: 20° Involute
12	0.210	0.245	27	0.314	0.349
13	0.220	0.261	30	0.320	0.358
14	0.226	0.276	34	0.327	0.371
15	0.236	0.289	38	0.336	0.383
16	0.242	0.295	43	0.346	0.396
17	0.251	0.302	50	0.352	0.408
18	0.261	0.308	60	0.358	0.421
19	0.273	0.314	75	0.364	0.434
20	0.283	0.320	100	0.371	0.446
21	0.289	0.327	150	0.377	0.459
23	0.295	0.333	300	0.383	0.471
25	0.305	0.339	Rack	0.390	0.484

END THRUST ON BEVEL GEARS

In designing bearings to be used with bevel and mitre gears it is important to know the end thrust exerted by the bevel gears and pinions so that proper end thrust bearings may be provided.

The method of calculation of end thrusts is as follows:

A = Pressure angle of the gear teeth

P = Tooth Pressure at middle of tooth face

F = Separating Force = PxTan A

B = Pitch angle of Pinion

T = Thrust on pinion = P x Tan A x Sin B

T_1 = Thrust on gear = P x Tan A x Cos B

The following table gives the factors by which the tooth pressure is multiplied to find the thrust which give practically the same values found by solving the formulae for T & T_1 given above.

Gear Ratio	PRESSURE ANGLE A: 14½° Gear	14½° Pinion	15° Gear	15° Pinion	20° Gear	20° Pinion	22° Gear	22° Pinion
1 -1	.183	.183	.189	.189	.257	.257	.286	.286
1½-1	.215	.143	.223	.148	.303	.202	.336	.224
2 -1	.232	.116	.239	.120	.325	.163	.361	.181
2½-1	.240	.096	.249	.100	.338	.135	.375	.150
3 -1	.246	.082	.254	.085	.345	.115	.383	.128
3½-1	.249	.071	.258	.074	.350	.100	.389	.111
3¾-1	.250	.067	.259	.069	.352	.094	.390	.104
4 -1	.251	.062	.260	.065	.353	.088	.392	.097
4½-1	.253	.056	.262	.058	.355	.079	.394	.087
5 -1	.254	.051	.263	.053	.357	.072	.396	080
5½-1	.255	.046	.264	.048	.358	.065	.398	.072

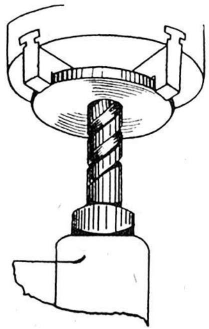
Fitting a Chuck Plate to a Chuck

Before a chuck can be used on a lathe it must be fitted with a chuck plate that has been threaded to fit the spindle nose of the lathe. Semi-machined chuck plates that have been accurately threaded to fit the lathe spindle can be obtained from the lathe manufacturer.

APPROXIMATE WEIGHTS OF CAST IRON GEARS

Diam. Inches	Pitch In.	5/16	3/8	1/2	5/8	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3
	Face In.	1 1/16	1 1/4	1 9/16	1 7/8	2 1/4	2 1/2	3	4	5	6	7	7 1/2	8	9
6	......	5	7	11	13	16	......	......	......	......	......	......	......	......	......
8	......	6	9	13	15	18	......	......	......	......	......	......	......	......	......
10	......	8	11	16	18	21	......	......	......	......	......	......	......	......	......
12	......	10	19	24	27	33	50	66	92	120	150	175	195	224	252
15	......	18	27	35	38	40	58	75	108	167	238	286	315	342	390
18	......	25	36	40	40	48	64	86	134	196	282	350	390	432	498
21	......	35	47	59	64	69	82	109	164	235	324	413	465	536	630
24	......	41	58	71	73	78	98	130	200	279	365	476	540	632	768
27	......	57	69	79	83	86	105	142	228	315	408	525	617	736	906
30	......	65	78	91	95	99	120	160	252	344	456	567	666	784	963
33	......	74	90	104	109	114	138	190	277	378	487	616	712	824	1017
36	......	85	103	118	124	130	150	207	292	407	516	651	757	880	1089
39	......	97	116	133	137	142	163	220	303	435	564	700	847	992	1170
42	......	110	134	149	157	168	183	230	320	469	600	763	945	1064	1233
45	......	......	......	......	......	......	190	240	346	500	666	854	1005	1136	1440
48	......	......	......	......	......	......	202	250	420	571	743	938	1065	1216	1530
51	......	......	......	......	......	......	215	275	487	646	816	1029	1160	1336	1659
54	......	......	......	......	......	......	230	305	541	714	888	1120	1275	1392	1746
57	......	......	......	......	......	......	245	330	560	755	976	1232	1365	1520	1808
60	......	......	......	......	......	......	268	360	573	801	1029	1358	1582	1816	2196
66	......	......	......	......	......	......	297	395	651	917	1290	1561	1800	2064	2500
72	......	......	......	......	......	......	332	440	731	1019	1357	1736	2018	2320	2800
78	......	......	......	......	......	......	373	485	811	1144	1519	1946	2271	2624	3132
84	......	......	......	......	......	......	424	535	905	1265	1680	2149	2505	2880	3477
90	......	......	......	......	......	......	......	......	......	1403	1920	2373	2758	3176	3843
96	......	......	......	......	......	......	......	......	......	1535	2028	2597	3022	3480	4217
102	......	......	......	......	......	......	......	......	......	......	2226	2842	3315	3840	4626
108	......	......	......	......	......	......	......	......	......	......	2412	3080	3600	4136	5000
114	......	......	......	......	......	......	......	......	......	......	2647	3353	3900	4464	5380

NOTE—The above are safe weights for estimating Spur Gears. These weights will vary according to bores, hubs, etc. Bevel Gears will average from ten to twenty per cent less in weight than Spur Gears. This table is published simply as a help in estimating freight costs and for engineers in figuring supports, etc.



If hole is to be just a rough job both as to size and straightness, use large drill $\frac{1}{64}''$ or $\frac{1}{32}''$ smaller than finish size, and run through piece. Drill is held in taper hole in tailstock spindle if taper shank drill is used, or in drill chuck mounted in tailstock spindle if straight shank drill is used.

THE SIZING AND CUTTING OF GEARS

Diameter, when applied to gears, is always understood to mean the pitch diameter.

Diametral Pitch is the number of teeth to each inch of the pitch diameter.

Example. If a gear has 40 teeth and the pitch diameter is 4 inches, there are 10 teeth to each inch of the pitch diameter and the diametral pitch is 10, or, in other words, the gear is 10 diametral pitch.

Diametral Pitch required, circular pitch given. Divide 3.1416 by the circular pitch.

Example. If the circular pitch is 2 inches, divide 3.1416 by 2 and the quotient, 1.5708, is the diametral pitch.

Diametral Pitch required, number of teeth and outside diameter given. Add 2 to the number of teeth and divide by the outside diameter.

Example. If the number of teeth is 40, the diameter of the blank is 10½ inches; add 2 to the number of teeth, making 42, and divide by 10½; the quotient, 4, is the diametral pitch.

Circular Pitch is the distance from the center of one tooth to the center of the next measured along the pitch circle.

Example. If the distance from the center of one tooth to the center of next tooth, measured along the pitch circle, is ½ inch, the gear is ½ inch circular pitch.

Circular Pitch required, diametral pitch given. Divide 3.1416 by the diametral pitch.

Example. If the diametral pitch is 4, divide 3.1416 by 4, and the quotient, .7854 inch, is the circular pitch.

Number of Teeth required, pitch diameter and diametral pitch given. Multiply the pitch diameter by the diametral pitch.

Example. If the diameter of the pitch circle is 10 inches and the diametral pitch is 4, multiply 10 by 4, and the product, 40, will be the number of teeth in the gear.

Number of Teeth required, outside diameter and diametral pitch given. Multiply the outside diameter by the diametral pitch and subtract 2.

Example. If the whole diameter is 10½ inches and the diametral pitch is 4, multiply 10½ by 4, and the product, 42, less 2, or 40, is the number of teeth.

Pitch Diameter required, number of teeth and diametral pitch given. Divide the number of teeth by the diametral pitch.

Example. If the number of teeth is 40 and the diametral pitch is 4, divide 40 by 4, and the quotient, 10, expressed in inches, is the pitch diameter.

Outside Diameter or size of gear blank required, number of teeth and diametral pitch given. Add 2 to the number of teeth and divide by the diametral pitch.

Example. If the number of teeth is 40 and the diametral pitch is 4, add 2 to the 40, making 42, and divide by 4; the quotient, 10½, is the whole diameter of the gear or blank.

Thickness of Tooth at Pitch Line required. Divide the circular pitch by 2, or 1.57 by the diametral pitch.

Example. If the circular pitch is 1.047 inches, or the diametral pitch is 3, divide 1.047 by 2, or 1.57 by 3, and the quotient, .523 inch, is the thickness of tooth.

Whole Depth of Tooth required. Divide 2.157 by the diametral pitch.

Example. If the diametral pitch of a gear is 6, the whole depth is 2.157 divided by 6, which equals .3595.

Whole Depth of Tooth is about 11/16 or exactly .6866 of the circular pitch.

Example. If the circular pitch is 2 inches, the whole depth of tooth is .6866 X 2 inches, or 1⅜ inches nearly.

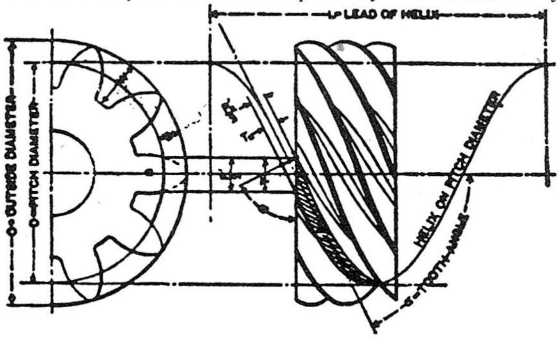
Distance between Centers of two gears required. Add the number of teeth together and divide one half the sum by the diametral pitch.

Example. If two gears have 50 and 30 teeth, respectively, and are 5 pitch, add 50 and 30, making 80, divide by 2, and then divide the quotient, 40, by the diametral pitch, 5, and the result, 8 inches, is the center distance.

INSTRUCTIONS ON SPIRAL GEARS

The art of designing helical or "spiral" gears opens with an apology. The subject is one which, from its very nature, can be approached by any one of a number of different ways. It has been approached by so many of these possible different ways that perhaps the subject has become quite confused in the minds of many technical readers

We show on page 52 the drawing with illustrating terms used in calculations of spiral gear. The normal diametral pitch, or diametral pitch of the cutter used, is reckoned from measurements taken along the pitch cylinder at right angles to the length of the tooth. P' represents the regular circular pitch, while P'n represents the normal circular pitch. The diametral pitch may be found from this by dividing 3.1416 by



P'n. This is the pitch of the cutter to be used. The cutter cannot be selected for the actual number of teeth in the gear, but must take into account the helix angle of the teeth as well, since the curvature as measured on a line at right angles to the helix is at a greater radius than when measured on the circle. The length of the helix, or the lead, as shown in the above drawing, is the length of pitch cylinder required to permit one complete revolution of the tooth if the latter were carried around for the full length of this cylinder The addendum S and whole depth W of the tooth for helical gears is the same as for plain spur gears.

The normal thickness of tooth at the pitch line, Tn, as shown in the above drawing, is measured in a direction perpendicular to the face of the tooth. The regular tooth thickness is shown at T, but with this we are not concerned. The outside diameter, as for spur gears, is found by adding twice the addendum to the pitch diameter.

CIRCULAR PITCH FORMULAS

Circular Pitch is the Distance from Centre of One Tooth to Centre of the Next Tooth, Measured along the Pitch Circle.

To Obtain	Having	Rule
Circular Pitch	Diametral Pitch.	Divide 3.1416 by the Diametral Pitch.
Circular Pitch	Pitch Diameter and the Number of Teeth.	Divide Pitch Diameter by the product of .3183 and Number of Teeth.
Circular Pitch	Outside Diameter and the Number of Teeth.	Divide Outside Diameter by the product of .3183 and Number of Teeth plus 2.
Pitch Diameter	Number of Teeth and the Circular Pitch.	The continued product of the Number of Teeth, the Circular Pitch and .3183.
Pitch Diameter	Number of Teeth and the Outside Diameter.	Divide the product of Number of Teeth and Outside Diameter by Number of Teeth plus 2.
Pitch Diameter	Outside Diameter and the Circular Pitch.	Subtract from the Outside Diameter the product of the Circular Pitch and .6366.
Outside Diameter	Number of Teeth and the Circular Pitch.	The continued product of the Number of Teeth plus 2, the Circular Pitch and .3183.
Outside Diameter	Pitch Diameter and the Circular Pitch.	Add to the Pitch Diameter the product of the Circular Pitch and .6366.
Outside Diameter	Number of Teeth and the Addendum.	Multiply Addendum by Number of Teeth plus 2.
Number of Teeth	Pitch Diameter and the Circular Pitch.	Divide the product of Pitch Diameter and 3.1416 by the Circular Pitch.
Thickness of Tooth	Circular Pitch.	One half the Circular Pitch.
Addendum	Circular Pitch.	Multiply the Circular Pitch by .3183, or $s = \frac{D'}{N}$.
Whole Depth	Circular Pitch.	Multiply the Circular Pitch by .6866.
Clearance	Circular Pitch.	Multiply the Circular Pitch by .05.

DIAMETRAL PITCH FORMULAS

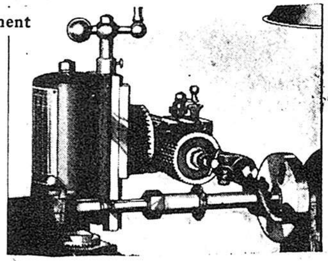
Diametral Pitch is the Number of Teeth to Each Inch of the Pitch Diameter

To Obtain	Having	Rule
Diametral Pitch	Circular Pitch.	Divide 3.1416 by the Circular Pitch.
Diametral Pitch	Pitch Diameter and the Number of Teeth.	Divide Number of Teeth by Pitch Diameter.
Diametral Pitch	Outside Diameter and the Number of Teeth.	Divide Number of Teeth plus 2 by Outside Diameter.
Pitch Diameter	Number of Teeth and the D.P.	Divide Number of Teeth by the Diametral Pitch.
Pitch Diameter	Number of Teeth and Outside Diameter.	Divide the product of Outside Diameter and Number of Teeth by Number of Teeth plus 2.
Pitch Diameter	Outside Diameter and the Diametral Pitch.	Subtract from the Outside Diameter the quotient of 2 divided by the Diametral Pitch.
Outside Diameter	Number of Teeth and the D.P.	Divide Number of Teeth plus 2 by the D.P.
Outside Diameter	Pitch Diameter and the Diametral Pitch.	Add to the Pitch Diameter the quotient of 2 divided by the Diametral Pitch.
Outside Diameter	Pitch Diameter and the Number of Teeth.	Divide the Number of Teeth plus 2 by the quotient of Number of Teeth divided by the Pitch Diameter.
Number of Teeth	Pitch Diameter and the D.P.	Multiply Pitch Diameter by the Diametral Pitch.
Number of Teeth	Outside Diameter and the Diametral Pitch.	Multiply Outside Diameter by the Diametral Pitch and subtract 2.
Thickness of Tooth	Diametral Pitch.	Divide 1.5708 by the D.P.
Addendum	Diametral Pitch.	Divide 1 by the D.P.
Whole Depth (B&S)	Diametral Pitch.	Divide 2.157 by the Diametral Pitch.
Whole Depth (Fellows)	Diametral Pitch.	Up to 16 D.P. inc. $= \frac{2.25}{D.P.}$ 17 to 32 D.P. inc. $= \frac{2}{D.P.} + .015$ 33 to 40 D.P. inc. $= \frac{2}{D.P.} + .010$
Clearance (B&S)	Diametral Pitch.	Divide .157 by the D.P.
Clearance (Fellows)	Diametral Pitch	Up to 16 D.P. inc. $= \frac{.250}{D.P.}$ 17 to 32 D.P. inc. = .015 33 to 40 D.P. inc. = .010

Cutting Gears on the Lathe

The gear cutting attachment for the lathe, shown in Fig. 1. will cut spur and bevel gears of all kinds. It will do graduating and milling, external key seating, cutting at angles, splining, slotting and all regular dividing head milling work.

Gear Cutting Attachment



SPIRAL GEAR CUTTING

Spiral gears may have their axes parallel, the same as spur gears, or the axes may be at an angle with each other. A spiral gear differs from a spur gear in that the teeth are not placed parallel with the axis, but are wound spirally around the pitch circle. The name "spiral gears" is really wrong. The teeth are not wound in a SPIRAL, but in a HELIX around the pitch circle. The distinction between a spiral and a helix will be clear when we remember that the main spring of a watch is a good example of a spiral, while the threads on a lead screw form a helix. However, in our discussion, we will use the name "spiral gears," as this is the name by which the average mechanic knows them. This chapter will not treat of all the properties of spiral gears, but only of such as need be known in order to design or make them.

If we have two shafts with a center distance of 7¼", and we must drive one shaft from the other with a given speed ratio, we will find considerable trouble if we try to use spur gears. If, for instance, the speed ratio is 4 to 5, we will not be able to use spur gears except by making them 18 pitch. The sum of the diameters is 14½", being twice the center distance, and we must select the pitch so that the sum of the numbers of teeth of the two gears can be split up into two numbers which have a ratio of 4 and 5. If we should select 4 pitch for the gears, we would find that the sum of the numbers of teeth of these two gears is 4 times the sum of their diameters, or 4 times 14½ equals 58. However, 58 can not be split up into two numbers which have a ratio of 4 and 5. In order to do so, 58 should be divisible by 4 plus 5 which equals 9. If we should select 5-pitch gears, then the sum of the numbers of teeth of the two gears would be $5 \times 14\frac{1}{2} = 72\frac{1}{2}$, and this, of course, is impossible, as the sum of the number of teeth of two gears must be an integral number. If we make the pitch 18, then the sum of the numbers of teeth of the two gears would be $18 \times 14\frac{1}{2} = 261$, and

Continued on next page

one gear would have $\frac{4}{9}$ of 261 teeth, and the other gear $\frac{5}{9}$ of this number. However, 18 pitch is probably entirely too fine for the work we have to do, so that we must choose one of two things. We must either make special cutters with an odd pitch, or we must be satisfied with a compromise as to the gear ratio. The first of these two things is costly and consumes a great deal of time and the other may be absolutely prohibitive if an exact gear ratio is required.

Substituting spiral gears for spur gears would solve the question at once.

Definitions - Pitch, Lead, Normal Pitch, etc. A tooth of a spiral gear is much like the thread of a screw. It does not have the same cross section, nor is it meant to do the same kind of work, but in many respects the two are very similar. The distance from a point on a screw thread to the corresponding point on the next thread is called the PITCH. The distance the screw travels in an axial direction, if we give it one complete turn, is called the LEAD. These same terms apply in the same way to a spiral gear. There is, however, this distinction: We measure the pitch of a screw along the axis of the screw, whereas, we measure the pitch of a spiral gear around the circumference, that is, at right angles to the axis. However, there are two things which are called pitch in the spiral gear. The pitch, as we described it, that is, the distance between two corresponding points of two adjoining teeth measured at right angles to the axis, is called the REAL pitch, whereas the distance between two corresponding points of two adjoining teeth, measured in a direction AT RIGHT ANGLES TO THE DIRECTION OF THE TEETH, is called the NORMAL pitch. The normal section, which would give us the normal pitch, would show us the true section of the teeth. A section, taken at right angles to the axis, would give us the distorted view of the shape of the teeth as seen when looking at the end of a spiral gear. A section through the axis would also give a distorted view. If the spiral angle is 45°, then the distorted views of the teeth would be the same whether we take the sections through the axis, or at right angles with the axis. If the angle of the spiral with the axis is less than 45°, that is, if the spiral gear approaches more nearly a spur gear, then the right angle section would give a less and the axial section a more distorted view. This is reversed if the angle of the spiral with the axis is more than 45°, that is, if the spiral gear approaches more nearly the shape of a worm.

Continued on next page

Cutting Spiral Gears. Spiral gears are ordinarily cut with common spur gear cutters. The normal pitch is, therefore, given in the same way as the pitch of spur gears, that is, we talk of a 5, a 7, or a 10-pitch gear. The real pitch is measured along the circular section of the gear, and if this pitch is P and the number of teeth of the gear is n, then the length of the circumference of the normal section is nP.

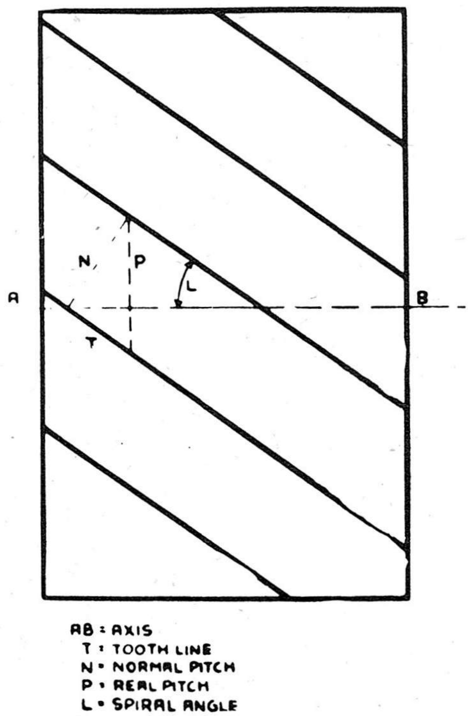


Fig. 1

Fig. 1 shows that the normal pitch and real pitch bear such a relation to each other that the normal pitch is a right angle side of a right angle triangle, of which the real pitch is the hypotenuse and the tooth line is the base. If the angle between the tooth line and the axis is called L, and if the normal pitch is P, then the real pitch is P-secant-L. If we know the pitch of the cutter, the number of teeth and the spiral angle, we can easily figure the pitch diameter of the spiral gear. We figure as if it were a spur gear and then multiply the diameter by the secant of the spiral angle. For instance, a

Continued on next page

spiral gear with 16 teeth, 5 pitch, and a spiral angle of 37 degrees, will have a diameter of 16 divided by 5 and multiplied by the secant of 37 degrees. If we were dealing with a spur gear the pitch diameter would be $\frac{16}{5} = 3.2''$.

From a table of secants we find sec 37° = 1.2521. Then we have $3.2 \times 1.2521 = 4.0064''$, the pitch diameter of the spiral gear.

The pitch circumference is $4.0067 \times \pi = 4.0067 \times 3.14159 = 12.587''$.

If we should make a wooden cylinder with a diameter equal to the pitch diameter of our spiral gear, and then cut out a paper right angle triangle, Fig. 2, of which one right angle side is equal to the circumference of the pitch circle, and the opposing angle equal

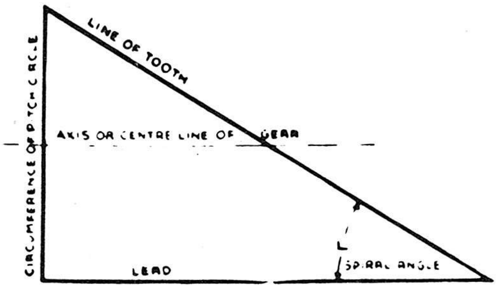


Fig. 2

to the spiral angle, and wrap this triangle around the cylinder, we will find that the hypotenuse describes a spiral line around the cylinder, and that the end of the hypotenuse will come in line with the beginning. In other words, the two ends of the hypotenuse will be a distance apart on the cylinder equal to the lead of the spiral. If now we unwrap the paper triangle we have in this triangle all the important elements of a tooth of the spiral gear. One right angle side is the circumference of the pitch circle, the second right angle side is the lead, the hypotenuse is the length of a tooth wrapped once around the pitch cylinder, the angle opposite the circumference is the angle of the spiral with the axis of the gear. This is commonly called the spiral angle or helix angle. It is the angle to which the milling machine table must be set. The angle opposite the lead is the angle which the tooth makes with the body of the gear.

Continued on next page

Addendum, dedendum and clearance are the same as in a spur gear of the same pitch as the normal pitch of the spiral gear.

Selecting the Cutter. It is now possible to figure all the dimensions of the spiral gear and turn up the blank in the lathe. However, when it comes to cutting the teeth, a new element comes in. Although the gear may have 16 teeth, 5 pitch, this does not mean that we can use a 16-tooth, 5-pitch gear cutter for this spiral gear. It is true, we will have to use a 5-pitch cutter, but not for 16 teeth. We must select a spur gear cutter for a different number of teeth. The rule usually given is to divide the number of teeth of the spiral gear by the cube of the cosine of the spiral angle.

This gives good results for gears having a spiral angle in the neighborhood of 45°, but anyone who has followed this rule for gears with a spiral angle differing greatly from 45° will have found that such gears do not run properly and the running of the gears becomes worse as the spiral differs more from 45°. For such gears we recommend the following rule:

Divide the number of teeth of the spiral gear by the product of the square of the cosine multiplied by the sine of the spiral angle.

$N = \dfrac{n}{\text{Cos } L^2 \times \sin L}$ in which N is the number of teeth of the selected gear cutter, and n is the number of teeth of the spiral gear.

Taking the above case

$$N = \frac{n}{\text{Cos } 37^2 \times \sin 37} = \frac{16}{.79864^2 \times .60182} = \frac{16}{.6378 \times .60182} = 41.$$

We should select a cutter suitable for cutting a gear with 41 teeth.

The speed ratio of two spiral gears is, as with spur gears, the ratio of their numbers of teeth. For instance, a 16-tooth gear driving a 32-tooth gear will cause this latter gear to run half as many revolutions per minute as the former. The center distance between two spiral gears, as with spur gears, is equal to half the sum of their pitch diameters.

Shafts Parallel. Computation of a pair of spiral gears which are to be used in place of spur gears.

If we have two shafts, say 8" apart, and wish to drive one from the other by means of spiral gears with a given gear ratio, and, if we desire to use standard gear cutters we should proceed as is shown in the following example:

Continued on next page

The two gears shown in Fig. 3, must have a ratio of 2 to 1; a center distance of 8", and in order to make them of the proper strength the teeth must have about 5 pitch. As we want to use standard gear cutters, we will make the pitch exactly 5.

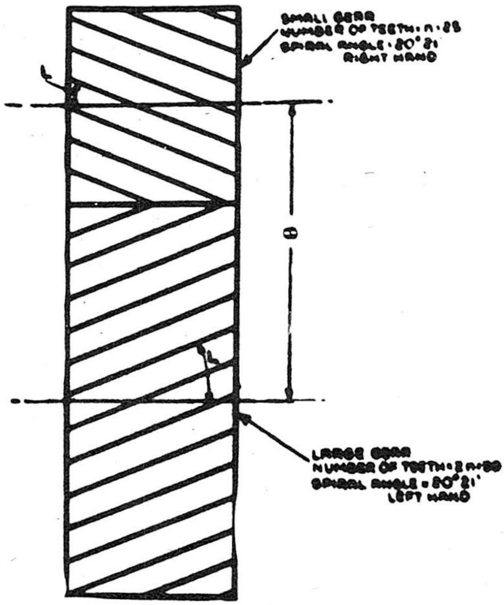


Fig. 3

A pair of spiral gears on parallel shafts to give a speed ratio of 2 to 1.

Number of Teeth and Spiral Angle. Taking the number of teeth in the small gear = n, and the number in the large gear = 2n, and the spiral angle of the teeth in the small gear L, we have:

Pitch diameter small gear $= \dfrac{n \sec L}{5}$, and

Pitch diameter large gear $= \dfrac{2n \sec L}{5}$, because, in a pair of spiral gears with shafts parallel, the spiral angle is the same in both.

The sum of the pitch diameters of the gears is, therefore

$$\frac{n \sec L}{5} + \frac{2n \sec L}{5}$$

and this sum equals double the center distance.

Continued on next page

Therefore,

$$\frac{n}{5} \sec L + \frac{2n}{5} \sec L = 16.$$

Multiplying both sides of this equation by 5, in order to simplify it, we get

$$n \sec L + 2n \sec L = 80.$$

This is a very simple equation, but unfortunately there are two unknown quantities: The number of teeth n, and the spiral angle L. However, there is one thing we know about n; it must be an INTEGRAL number. There is still another thing we know, and that is that we would like the angle to be about 20 degrees, for this gives the maximum efficiency of the gear system. We will, therefore, try the equation by giving L the value of 20°: sec 20 = 1.0642, and therefore the equation

$$n \sec L + 2n \sec L = 80$$

becomes $(n \times 1.0642) + (2n \times 1.0642) = 80.$

$$3n \times 1.0642 = 80.$$
$$n \times 3.1926 = 80.$$
$$n = 25.058.$$
$$2n = 50.116.$$

As n must be an integral number, we will assume a value of n = 25, and therefore 2n = 50.

Substituting in the above equation, we get

$$25 \times 1.0642 + 50 \times 1.0642 = 79.815.$$

Since the second member of the equation should be 80 and not 79.815, it is evident that the assumed value of 20° for L, the spiral angle will not do, if we decide to use 25 and 50 teeth. In proceeding to find the correct angle, we will first determine whether the angle should be more or less than 20°. For trial, we will select 19° and 21°. With 20° the value of the second member was too small. Therefore, it must be increased. Since our value is too small we will try a larger angle, 21°:

sec 21 = 1.0711. Substituting this in our equation, we get
$25 \times 1.0711 + 50 \times 1.0711 = 80.3325.$

Continued on next page

The value, using 20°, was .185 too small. Our new value is .3325 too large. The correct angle is, therefore, between 20° and 21°. By trial, we find that 20°22′ (sec 20°22′ = 1.0667) gives us

$$25 \times 1.0667 + 50 \times 1.0667 = 80.0025, \text{ or } .0025 \text{ too large,}$$

and 20°21′ (sec 20°21′ = 1.066) gives us

$$25 \times 1.0666 + 50 \times 1.0666 = 79.9950, \text{ or } .005 \text{ too small.}$$

We will, therefore, choose as our value of L, 20°21′. Let us try this out and find what the new center distance between the gears will be.

Since the gears are 5 pitch and we have taken 2 × center distance for our second member of the equation, then the center distance is

$$\frac{79.9950}{2 \times 5} = 7.99950$$

which is .0005″ short, which is close enough for all practical purposes.* Our gears, therefore, will have a spiral angle of 20°21′, the small one with 25 teeth and the large one with 50 teeth.

Selecting the Cutter. Referring back to the rule given on page 77, we have for the small gear

$$N = \frac{n}{\cos^2 20°21' \times \sin 20°21'} = \frac{25}{.93759^2 \times .34775} =$$

$$\frac{25}{.8780 \times .34775} = 81,$$

and for the large gear

$$\frac{50}{.93759^2 \times .34775} = \frac{50}{.8780 \times .34775} = 163.$$

Therefore, the cutters should be selected for 81 and 163 teeth respectively.

* We have already decided that the center distance between the shafts on which these gears will work in our machine is 8″. Were we to use an angle of 20° 22′, our gears would have a center distance .00025″ too large, and they would not go into place, or at least they would work too tight if all other dimensions were correct. We therefore choose 20° 21′ which makes gears that are .0005″ small and will have just this much working clearance. This is satisfactory for ordinary work. If closer accuracy is required we must either change our center distance in the machine or continue trying by selecting angles reading in seconds until a satisfactory one is found.

Continued on next page

Computing the Lead. Referring to Fig. 2 We know angle L = 20°21′. However, we do not know the pitch circumference. We must therefore first find the

PITCH DIAMETERS

$$\text{Pitch diameter} = \frac{n}{P} \times \sec L.$$

Then for the small gear we have

$$\frac{25}{5} \times \sec 20°21' = \frac{25}{5} \times 1.0666 = 5.3330,$$

and for the large gear

$$\frac{50}{5} \times \sec 20°21' = \frac{50}{5} \times 1.0666 = 10.666$$

Since the outside diameter equals the pitch diameter plus twice the addendum, $OD = PD + \frac{2}{P}$ therefore,

$$\text{outside diameter of small gear} = 5.3330 + \frac{2}{5} = 5.7330'';$$

$$\text{outside diameter of large gear} = 10.6660 + \frac{2}{5} = 11.0660''.$$

The PITCH CIRCUMFERENCES are:

small gear $5.333 \times 3.1416 = 16.754$
large gear $10.666 \times 3.1416 = 33.508.$

$$\text{Lead} = \frac{\text{pitch circumference}}{\text{Tangent } L} = \frac{16.754}{\text{Tangent } 20°21'} = \frac{16.754}{.37090} = 45.17''$$

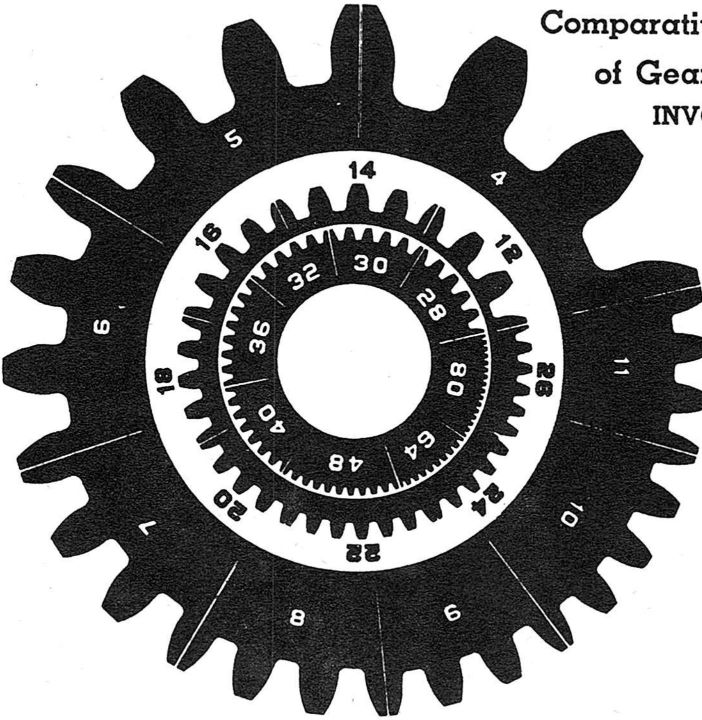
for the small gear, and $2 \times 45.17'' = 90.34''$ for the large gear.

We now proceed to select the change gears by following the instructions given in the chapter on Change Gears for Cutting Spirals.

Our gears are as follows, shafts parallel:

Pitch .... = 5.
Number of teeth in small gear .... = 25.
Number of teeth in large gear .... = 50.

Comparative Sizes of Gear Teeth
INVOLUTE



STRENGTH OF GEAR TEETH (Lewis)

W = load transmitted in pounds (force at pitch line of gear)
p' = circular pitch
f = face
y = factor for different numbers and forms of teeth (Table II)
s = safe working stress of material (Table I)
V = velocity in feet per minute
$W = s\ p'\ f\ y$

$$\text{Horsepower} = \frac{WV}{33000}$$

Table I—SAFE WORKING STRESS s IN POUNDS PER SQUARE INCH FOR DIFFERENT SPEEDS

Speed of Teeth in Ft. Per Min.	Cast Iron	Steel
100 or less	8000	20000
200	6000	15000
300	4800	12000
600	4000	10000
900	3000	7500
1200	2400	6000
1800	2000	5000
2400	1700	4300

Table II—VALUES OF FACTOR y FOR LEWIS' FORMULA

No. of Teeth	Value of Factor y		No. of Teeth	Value of Factor y	
	Involute 20°	Involute 15°		Involute 20°	Involute 15°
12	0.078	0.067	27	0.111	0.100
13	0.083	0.070	30	0.114	0.102
14	0.088	0.072	34	0.118	0.104
15	0.092	0.075	38	0.122	0.107
16	0.094	0.077	43	0.126	0.110
17	0.096	0.080	50	0.130	0.112
18	0.098	0.083	60	0.134	0.114
19	0.100	0.087	75	0.138	0.116
20	0.102	0.090	100	0.142	0.118
21	0.104	0.092	150	0.146	0.120
23	0.106	0.094	300	0.150	0.122
25	0.108	0.097	Rack	0.154	0.124

Table III—AVERAGE VALUES FOR s IN POUNDS PER SQUARE INCH

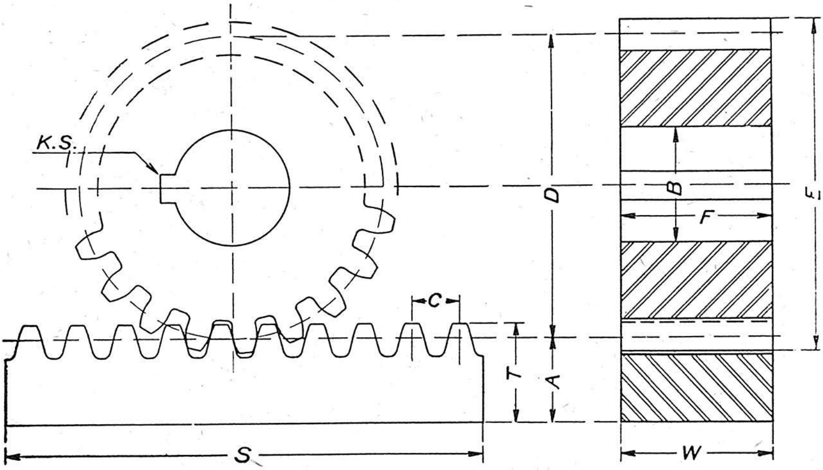
Material		S
Non-metallic		6000
Cast iron		8000
Bronze		8000
Steel	.20C Natural	12000
	.20C Case-hardened	25000
	.30C Natural	15000
	.40C "	20000
	.40C Heat-treated	30000

Lewis' Formula for the strength of gears originally read as above. The following revision by Barth provides a practical means for calculating the Horsepower of material of any known static stress and velocity.

S = static stress of material (Table III).

$$W = S\ p'\ f\ y\ \frac{600}{600 + V} \qquad \text{Horsepower} = \frac{WV}{33000}$$

MACHINE RACKS AND PINIONS



Rack

Pitch	Circular	= C
	Diametral	=3.1416 ÷ C
Thickness		= T
Face		= W
Length of Rack		= S
Material		=
Center of Pinion to Bottom of Rack		= A

Pinion

Number of Teeth		=
Pitch	Circular	= C
	Diametral	= *
Pitch Diameter		= D′
Outside Diameter		= E
Bore		= B
Face		= F
Keyway		= K.S.
Material		=

*Number of teeth to each inch of Pitch Diameter.

Use of Center Gauge

The point of the cutter bit must be ground to an angle of 60° for cutting American National screw threads in the lathe, as shown in Fig. 1 at right. A center gauge having a 60° included angle is used for grinding the tool to the exact angle required. The top of the tool is usually ground flat, with no side rake or back rake. However, for cutting threads in steel, side rake is sometimes used.

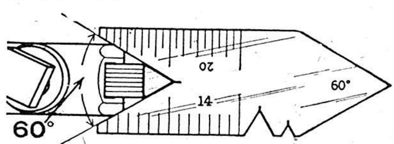
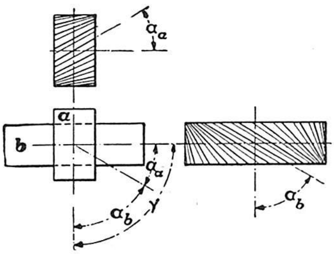


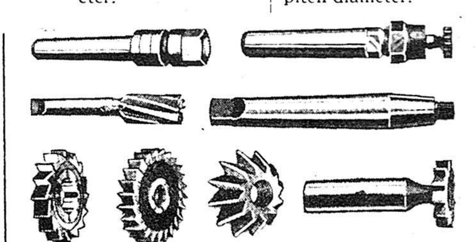
Fig. 1. Cutter Bit for Cutting Screw Threads is Ground to 60° Center Gauge

RULES AND FORMULAS FOR HELICAL GEAR CALCULATIONS

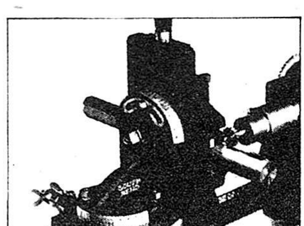


In the formulas, N, α, etc., are the numbers of teeth, spiral angle, etc., for *either* gear or pinion; the notation N_a, N_b, α_a, α_b, etc., refer to the teeth or angles in the pinion or gear, respectively, in a pair of gears *a* and *b*.

To Find	Rule	Formula
Relation between Shaft and Tooth Angles.	The sum of the tooth angles of a pair of mating helical gears is equal to the shaft angle.	$\gamma = \alpha_a + \alpha_b$
Pitch Diameter.	Divide the number of teeth by the product of the normal pitch and the cosine of the tooth angle.	$D = \dfrac{N}{P_n \cos \alpha}$
Center Distance.	Add together the pitch diameters of the two gears and divide by 2.	$C = \dfrac{D_a + D_b}{2}$
Checking Calculations in (2) and (3).	To prove the calculations for pitch diameters and center distance, multiply the number of teeth in the first gear by the tangent of the tooth angle of that gear, and add the number of teeth in the second gear to the product; the sum should equal twice the product of the center distance multiplied by the normal diametral pitch, multiplied by the sine of the tooth angle of the first gear.	$N_b + (N_a \times \tan \alpha_a) = 2CP_n \times \sin \alpha_a$
Number of Teeth for which to Select Cutter.	Divide the number of teeth in the gear by the cube of the cosine of the tooth angle.	$N' = \dfrac{N}{(\cos \alpha)^3}$
Lead of Tooth Helix.	Multiply the pitch diameter by 3.1416 times the cotangent of the tooth angle.	$L = \pi D \times \cot \alpha$
Addendum.	Divide 1 by the normal diametral pitch.	$S = \dfrac{1}{P_n}$
Whole Depth of Tooth.	Divide 2.157 by the normal diametral pitch.	$W = \dfrac{2.157}{P_n}$
Normal Tooth Thickness at Pitch	Divide 1.571 by the normal diametral pitch.	$T_n = \dfrac{1.571}{P_n}$
Outside Diameter.	Add twice the addendum to the pitch diameter.	$O = D + 2S$



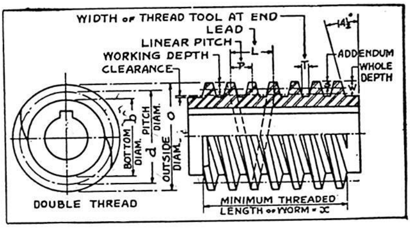
An Assortment of Milling Cutters and Arbors

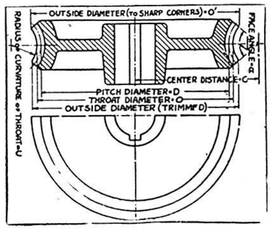


Milling a Woodruff Keyway in a Shaft

DESIGN OF WORM GEARING

The uses and advantages of worm gearing have been thoroughly covered





CALCULATION OF DIMENSIONS

P = circular pitch of wheel and linear pitch of worm;
l = lead of worm;
n = number of teeth or threads in worm;
S = addendum, or height of worm tooth above pitch line;
d = pitch diameter of worm;
D = pitch diameter of worm-wheel;
o = outside diameter of worm;
O = throat diameter of worm-wheel;
O' = outside diameter of worm-wheel (to sharp corners);
b = bottom or root diameter of worm;
N = number of teeth in worm-wheel;
W = whole depth of worm tooth;
T = width of thread tool at end;
α = face angle of worm-wheel;
β = helix angle of worm and gashing angle of wheel;
U = radius of curvature of worm-wheel throat;
C = distance between centers;
x = threaded length of worm.

RULES AND FORMULAE FOR WORM GEARING

To Find	Rule	Formula
Linear Pitch.	Divide the lead by the number of threads.—It is understood that by the number of threads is meant, not number of threads per inch, but the number of threads in the whole worm—one, if it is single-threaded, four, if it is quadruple-threaded, etc.	$P = \frac{l}{n}$
Addendum of Worm Tooth.	Multiply the linear pitch by 0.3183.	$S = 0.3183P$
Pitch Diameter of Worm.	Subtract twice the addendum from the outside diameter.	$d = o - 2S$
Pitch Diameter of Worm-wheel.	Multiply the number of teeth in the wheel by the linear pitch of the worm, and divide the product by 3.1416.	$D = \frac{NP}{3.1416}$
Center Distance between Worm and Gear.	Add together the pitch diameter of the worm and the pitch diameter of the worm-wheel, and divide the sum by 2.	$C = \frac{D+d}{2}$
Whole Depth of Worm Tooth.	Multiply the linear pitch by 0.6866.	$W = 0.6866P$
Bottom Diameter of Worm.	Subtract twice the whole depth of tooth from the outside diameter.	$b = o - 2W$
Helix Angle of Worm.	Multiply the pitch diameter of the worm by 3.1416, and divide the product by the lead; the quotient is the cotangent of the helix angle of the worm.	$\cot\beta = \frac{3.1416d}{l}$
Width of Thread Tool at End.	Multiply the linear pitch by 0.31.	$T = 0.31P$
Throat Diameter of Worm-wheel.	Add twice the addendum of the worm tooth to the pitch diameter of the worm-wheel.	$O = D + 2S$

(Continued on top of next page.)

RULES AND FORMULAE FOR WORM GEARING—Cont'd.

Radius of Worm-wheel Throat.	Subtract twice the addendum of the worm tooth from half the outside diameter of the worm.	$U = \frac{o}{2} - 2S$
Diameter of Worm-wheel to Sharp Corners.	Multiply the radius of curvature of the worm-wheel throat by the cosine of half the face angle, subtract this quantity from the radius of curvature, multiply the remainder by 2, and add the product to the throat diameter of the worm-wheel.	$O' = 2\left(U - U \times \cos\frac{a}{2}\right) + O$
Minimum Length of Worm for Complete Action.	Subtract four times the addendum of the worm thread from the throat diameter of the wheel, square the remainder, and subtract the result from the square of the throat diameter of the wheel. The square root of the result is the minimum length of worm advisable.	$x = \sqrt{O^2 - (O-4S)^2}$
Outside Diameter of Worm.	Add together the pitch diameter and twice the addendum.	$o = d + 2S$
Pitch Diameter of Worm.	Subtract the pitch diameter of the worm-wheel from twice the center distance.	$d = 2C - D$

Careful distinction must be made between the terms "pitch" and "lead." The term lead is defined as the distance which any one thread advances in one revolution of the worm, while the pitch, or, more correctly, the linear pitch, is the distance between the centers of two adjacent threads. The lead and pitch are equal for a single-threaded worm. For a double-threaded worm the lead is twice the linear pitch, and for a triple-threaded worm, three times the linear pitch.

TABLE OF CUTTERS, PITCHES, GEARS AND ANGLES FOR TWIST DRILLS

Diameter of Drill	Thickness of Cutter	Pitch in Inches	Gear on Worm	First Gear on Stud	Second Gear on Stud	Gear on Screw	Angle of Spiral
$\frac{1}{16}$	.06	.67	24	86	24	100	16° 20'
$\frac{1}{8}$	.08	1.12	24	86	40	100	19° 20'
$\frac{3}{16}$	.11	1.67	24	64	32	72	19° 25'
$\frac{1}{4}$	.15	1.94	32	64	28	72	21°
$\frac{5}{16}$	.19	2.92	24	64	56	72	20°
$\frac{3}{8}$	.23	3.24	40	48	28	72	21°
$\frac{7}{16}$	.27	3.89	56	48	24	72	20° 10'
$\frac{1}{2}$	.31	4.17	40	72	48	64	20° 30'
$\frac{9}{16}$	.35	4.86	40	64	56	72	20°
$\frac{5}{8}$	.39	5.33	48	40	32	72	20° 12'
$\frac{11}{16}$	.44	6.12	56	40	28	64	19° 30'
$\frac{3}{4}$	.50	6.48	56	48	40	72	20°
$\frac{13}{16}$	.56	7.29	56	48	40	64	19° 20'
$\frac{7}{8}$	.62	7.62	64	48	32	56	19° 50'
$\frac{15}{16}$	.70	8.33	48	32	40	72	19° 30'
1	.77	8.95	86	48	28	56	19° 20'
$1\frac{1}{8}$	85	9.33	56	40	48	72	20° 40'

CHANGE GEARS FOR MILLING SPIRALS ON THE MILLING MACHINE

The worm wheel in the universal indexing head of the milling machine has 40 teeth and the table feed screw usually has four threads per inch. It therefore requires 40 turns of the worm to rotate the spindle of the dividing head once, and it requires four turns of the feed screw to advance the milling machine table one inch. If gears of equal size were put on the feed screw and worm shafts and were geared directly (that is, simple, not compound, geared), 40 turns of the feed screw would cause one turn of the spindle and at the same time advance the table $\frac{1}{4} \times 40 = 10$ inches, giving a spiral with a pitch of 10 inches.

In calculations for spirals, we must have the ratio

$$\frac{\text{4 times pitch of spiral}}{40} \text{ equal to } \frac{\text{teeth in driven gear}}{\text{teeth in driving gear}}$$

Expressed in the form of a proportion, this is, 4 × pitch of spiral : 40 :: teeth in driven gear : teeth in driving gear. For example: If a spiral pitch of 6 inches were required, $6 \times 4 = 24$, which is the number of revolutions the screw must make while the work rotates through one revolution. Then the ratio

$$\frac{24}{40} = \frac{\text{teeth in driven gear}}{\text{teeth in driving gear}}$$

Put a 40-tooth gear on the feed screw and a 24-tooth gear on the worm shaft.

COMPOUND GEARING

It is best when possible to use the simple gearing. If, however, the ratio is such that one of the gears would be extremely large or small, then the gearing should be compounded. For example: Required pitch of spiral $32\frac{1}{2}$ inches, $32\frac{1}{2} \times 4 = 130$, or the revolutions of the screw per revolution of the work.

$$\frac{130}{40} = \frac{\text{No. teeth in driven gear}}{\text{No. teeth in driving gear}}$$

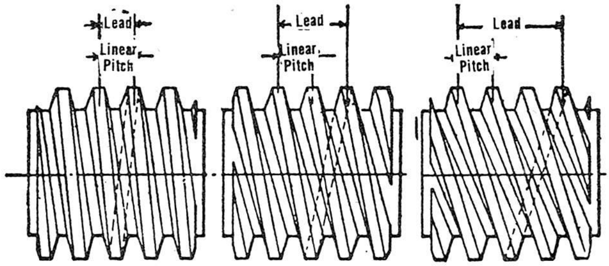
As 130 would be a rather large gear, and probably not furnished with the machine, we can reduce the ratio to $\frac{65}{20}$, but this would also give numbers of teeth not usually furnished. It would then be necessary to compound. Resolve the ratio $\frac{130}{40}$ into factors $\frac{10}{5} \times \frac{13}{8}$; as these numbers are too low, we can multiply both numerator and denominator by the same number, and we would have, for example, $\frac{10}{5} \times \frac{4}{4} = \frac{40}{20}$ and $\frac{13}{8} \times \frac{4}{4} = \frac{52}{32}$ and as $\frac{40}{20} \times \frac{52}{32}$ = the ratio $\frac{130}{40}$ we may use gears 40 and 52 as the driven gears. Either 20 or 32 can be placed on the screw and the other will be the inside gear on the stud. Either the 40 or 52 can be put on the worm shaft and the other will be the outside gear on the stud. If any of the gears called for were not found in the regular set, the numbers could be changed by treating both numerator and denominator without changing the ratio. Thus, in the last problem, if the last set did not contain a gear tooth of 20 teeth, we could divide both numerator and denominator by a common factor and multiply the results by some other number. Thus in the ratio $\frac{40}{20}$ divide both by 5, giving $\frac{8}{4}$ and multiply both by 6. This would give $\frac{48}{24}$ which alters the numbers, but does not change the ratio. In this manner it is usually possible to so manipulate the ratios that the exact or a very close approximation to the required pitch can be obtained with the regular gears.

INSTRUCTIONS ON WORM GEARS

We show on the next page three worms. The first one is a single-threaded; the second one is a double-threaded; the third one is a triple-threaded. The word "lead" is assumed to mean the distance, which a given thread advances in one revolution of the worm, while by "pitch," or, more strictly, "linear pitch," we mean the distance between the centers of two adjacent threads. As may be clearly seen, the lead and linear pitch are equal for a single-threaded worm. For a double-threaded worm the lead is twice the linear pitch, and for a triple-threaded worm it is three times the linear pitch. It is understood, of course, that by the number of threads is meant, not the number of threads per inch, but the number of threads in the whole worm — one, if it is single-threaded; four, if it is quadruple-threaded, etc.

The standard form of worm thread, measured, has the same dimensions as the standard form of involute rack tooth of the same linear or circular pitch. It is not of exactly the same shape, however, not being rounded at the top, nor provided with fillets. The thread is cut with a straight-sided tool having a square flat end. The sides have an inclination with each other of 29 degrees, or $14\frac{1}{2}$ degrees with the center line. The following rules in the next table will give the dimensions of the teeth in various linear pitches.

Continued on next page



The above drawing shows the distinction between the terms lead and linear pitch as applied to worm gears.

RULES FOR CALCULATING WORM GEARS

No. 1 Rule. To find the lead of a worm, multiply the linear pitch by the number of threads.

No. 2 Rule. To find the linear pitch of a worm, divide the lead by the number of threads.

No. 3 Rule. To find the whole depth of the worm tooth, multiply the linear pitch by 0.6866.

No. 4 Rule. To find the width of the thread tool at the end, multiply the linear pitch by 0.31.

No. 5 Rule. To find the addendum or height of worm tooth above the pitch line, multiply the linear pitch by 0.3183.

No. 6 Rule. To find the outside diameter of the worm, add together the pitch diameter and twice the addendum.

No. 7 Rule. To find the pitch diameter of the worm, subtract twice the addendum from the outside diameter.

No. 8 Rule. To find the bottom diameter of the worm, subtract twice the whole depth of tooth from the outside diameter.

No. 9 Rule. To find the helix angle of the worm and the gashing angle and the worm wheel tooth, multiply the pitch diameter of the worm by 3.1416, and divide the product by the lead; the quotient is the cotangent of the tooth angle of the worm

No. 10 Rule. To find the pitch diameter of the worm wheel, multiply the number of teeth in the wheel by the linear pitch of the worm, and divide the product by 3.1416.

No. 11 Rule. To find the throat diameter of the worm wheel, add twice the addendum of the worm tooth to the pitch diameter of the worm wheel.

No. 12 Rule. To find the radius of curvature of the worm wheel throat, subtract twice the addendum of the worm tooth from the outside diameter of the worm.

No. 13 Rule. To find the diameter of the worm wheel to sharp corners, multiply the throat radius by the cosine of the half the face angle, subtract this quantity from the throat radius, multiply the remainder by 2, and add the product to the throat diameter of the worm wheel.

No. 14 Rule. To find the velocity ratio of a worm and worm wheel, divide the number of teeth in the wheel by the number of threads in the worm.

No 15 Rule To find the distance between the center of the worm wheel and the center of the worm, add together the pitch diameter of the worm and the pitch diameter of the worm wheel, and divide the sum by 2

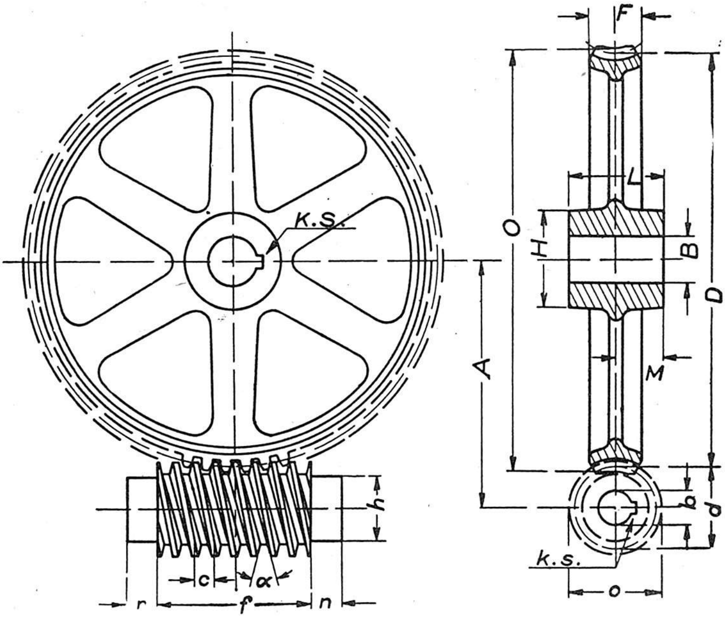
No 16 Rule To find the pitch diameter of the worms, subtract the pitch diameter of the worm wheel from twice the center distance

No. 17 Rule. To find the minimum length of worms for complete action with the worm wheel, subtract four times the addendum of the worm thread from the throat diameter of the wheel, square the remainder, and subtract the result from the square of the throat diameter of the wheel. The square root of the result is the minimum length of worm advisable.

No. 18 Rule. The length of the worms should ordinarily be longer than the dimension thus found. Hobs, particularly, should be long enough for the largest wheels they are ever likely to be called upon to cut.

No. 19 Rule. The throat diameter of the wheel and the center distance may have to be altered in some cases from the figures given by the preceding rules If worm wheels with small numbers of teeth are made to the dimensions given, it will be found that the flanks of the teeth will be partly cut away by the tops of the hob teeth, so that the full bearing area is not available. The matter becomes serious when there are less than 25 teeth in the worm wheel There are two ways of avoiding the difficulty. One of them is to increase the included angle of the sides of the thread tool. This departure from standard form, however, may be avoided by an increase in the throat diameter of the wheel, and consequently in the center distance On the other hand, some designers claim to get better results in efficiency and durability by making the throat diameter of the worm wheel smaller than standard, where it is possible to do so without too much under cutting.

WORMS AND WORM GEARS



WORM GEAR

Number of Teeth............
Pitch (Circular)..............=C
Face.......................=F
Bore.......................=B
Pitch Diameter..............=D
Length through Hub.........=L
Projection from Center.......=M
Keyway...................=KS
Material....................
Right or Left Hand..........

WORM

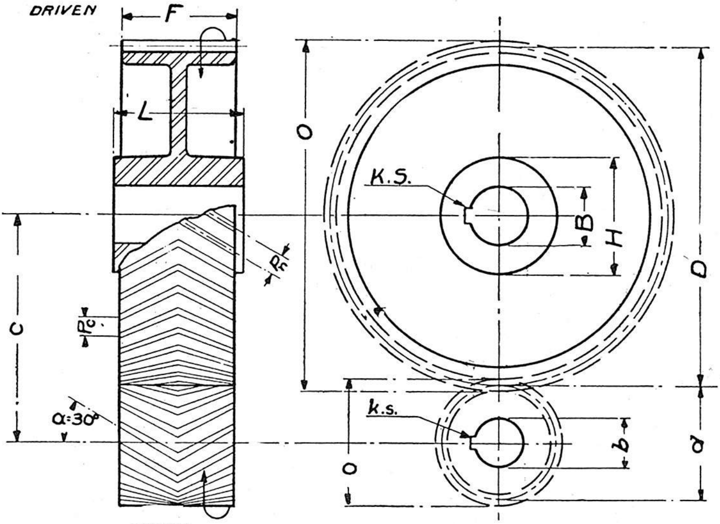
Pitch.......................=c
(Distance from center to center of teeth.)
Lead (Advance in one revolution.)
Pitch Diameter...............=d
Outside Diameter............=d'
Bore.......................=b
Length.....................=f
Projection of Hub............=n
Keyway...................=ks
Material....................
Right or Left Hand..........

Distance between Centers...................=A

Table of Observed Tooth Dimensions for Spiral Gears

Angle of Table Setting, Degrees	Width of Tooth at a Depth of Inches						
	0	0.050	0.100	0.125	0.150	0.200	0.250
45	0.104	0.145	0.185	0.200	0.203	0.221	0.239
44	0.102	0.144	0.181	0.195	0.202	0.220	0.238
43	0.099	0.142	0.176	0.188	0.200	0.218	0.236
42	0.094	0.135	0.168	0.180	0.196	0.215	0.234
41	0.087	0.128	0.158	0.171	0.185	0.211	0.232
40	0.078	0.115	0.146	0.158	0.171	0.205	0.230

HERRINGBONE GEARS



GEAR		PINION	
Circular Pitch (Circumferential)	= Pc	Circular Pitch (Circumferential)	= Pc
Normal Circular Pitch	= Pn	Normal Circular Pitch	= Pn
Pitch Diameter	= D	Pitch Diameter	= d
Outside Diameter	= O	Outside Diameter	= o
Center Distance	= C	Center Distance	= C
No. of Teeth	= N	No. of Teeth	= n
Face	= F	Face	= F
Length of Hub	= L	Length of Hub	= l
Bore	= B	Bore	= b
Key seat	= KS	Keyseat	= ks

Helix Angle = 30° on all gears and pinions.

All Herringbone gears are figured on the basis of Diametrical pitch.
Diametrical pitch = 3.1416 divided by the circular pitch.

Allowance Tables for Bores of Gears

RUNNING FIT ALLOWANCE				DRIVE FIT ALLOWANCE			
Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
¼	.00058	7	.0027	¼	.00035	7	.0040
½	.00065	8	.0030	½	.0005	8	.0045
¾	.00073	9	.0033	¾	.0005	9	.0050
1	.0008	10	.0036	1	.0010	10	.0055
1½	.0010	11	.0039	1½	.0013	11	.0060
2	.0011	12	.0043	2	.0015	12	.0065
3	.0014	14	.0049	3	.0020	14	.0075
4	.0018	16	.0055	4	.0025	16	.0085
5	.0021	18	.0061	5	.0030	18	.0095
6	.0024	20	.0068	6	.0035		

Module System Translation

FORMULAS

Module is the Pitch diameter in m/m divided by number of teeth in the gear.

Or, the outside diameter in m/m divided by the number of teeth in gear plus 2.

To find circular pitch in millimeters from Module multiply 3.142 m/m by the number of module .'. 2 module × 3.142 m/m = 6.284 m/m.

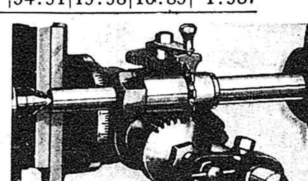
To find circular pitch in inches from the circular pitch in m/m, multiply the number of m/m by .03937" .'. 6.284 m/m × .03937 = .2474".

To find diametral pitch from circular pitch in inches, divide 3.1416 by the circular pitch in inches .'. 3.1416÷.2474"=12.6999 diametral pitch.

MODULE—TABLE OF TOOTH PARTS

Module m/m	Circular Pitch m/m	Thickness of Tooth at Pitch Line m/m	Addendum m/m	Dedendum m/m	Clearance m/m	Working Depth of Tooth m/m	Total Height of Tooth m/m	Width of Thread Tool at End m/m	Width of Thread at End m/m	Nearest English Diametral Pitch
M	Pc	t	a	d	c	a_2	H	T'	T	Pd
.50	1.57	.78	.50	.58	.08	1	1.08	.48	.52	50.800
.75	2.36	1.18	.75	.87	.12	1.50	1.62	.73	.78	33.866
1	3.14	1.57	1	1.16	.16	2	2.16	.97	1.05	25.400
1.25	3.93	1.96	1:25	1.45	.20	2.50	2.70	1.21	1.31	20.320
1.50	4.71	2.36	1.50	1.73	.23	3	3.23	1.46	1.57	16.933
1.75	5.50	2.75	1.75	2.02	.27	3.50	3.77	1.70	1.84	14.514
2	6.28	3.14	2	2.31	.31	4	4.31	1.94	2.10	12.700
2.25	7.07	3,53	2.25	2.60	.35	4.50	4.85	2.19	2.37	11.288
2.50	7.85	3.93	2.50	2.89	.39	5	5.39	2.43	2.63	10.160
2.75	8.64	4.32	2.75	3.18	.43	5.50	5.93	2.68	2.89	9.236
3	9.42	4.71	3	3.47	.47	6	6.47	2.92	3.15	8.466
3.50	10.99	5.50	3.50	4.05	.55	7	7.55	3.40	3.68	7.257
4	12.57	6.28	4	4.63	.63	8	8.63	3.89	4.20	6.350
4.50	14.14	7.07	4.50	5.21	.71	9	9.71	4.38	4.73	5.644
5	15.71	7.85	5	5.78	.78	10	10.78	4.87	5.26	5.080
5.50	17.28	8.64	5.50	6.36	.86	11	11.86	5.35	5.79	4.618
6	18.85	9.42	6	6.94	.94	12	12.94	5.84	6.31	4.233
7	21.99	10.99	7	8.10	1.10	14	15.10	6.81	7.36	3.628
8	25.13	12.57	8	9.26	1.26	16	17.26	7.79	8.42	3.175
9	28.27	14.14	9	10.41	1.41	18	19.41	8.76	9.47	2.822
10	31.42	15.71	10	11.57	1.57	20	21.57	9.73	10.52	2.540
11	34.56	17.28	11	12.73	1.73	22	23.73	10.71	11.57	2.309
12	37.70	18.85	12	13.88	1.88	24	25.88	11.68	12.63	2.116
14	43.98	21.99	14	16.20	2.20	28	30.20	13.63	14.73	1.814
16	50.26	25.13	16	18.51	2.51	32	34.51	15.58	16.83	1.587

The dividing head construction is based on the principle of interchangeable gears, the same as regularly used on gear cutting machines. The index plate shows the proper gears to use for divisions from 2 to 360.



Cutting a Gear on a Lathe

Formulas for Determining the Dimensions of Gears by Metric Pitch

Module is the pitch diameter in millimeters divided by the number of teeth in the gear.

Pitch diameter in millimeters is the Module multiplied by the number of teeth in the gear.

$M = \frac{D'}{N}$ or $\frac{D}{N+2}$ = Module

$D' = N\ M$ = The pitch diameter of gear in millimeters

$D = (N + 2)\ M$ = The whole diameter of gear in millimeters

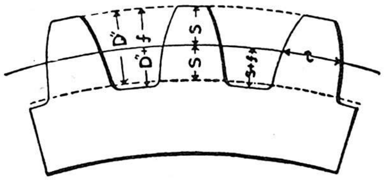
$N = \frac{D'}{M}$ or $\frac{D}{M} - 2$ = The number of teeth in gear

$D'' = 2\ M$ = The working depth of teeth

$t = M\ 1.5708$ = Thickness of teeth on pitch line

$f = \frac{M\ 1.5708}{10} = .157\ M$ = Amount added to depth for clearance

The Module is equal to the part marked "S" in cut opposite, measured in millimeters and parts of millimeters.



Pitches Commonly Used

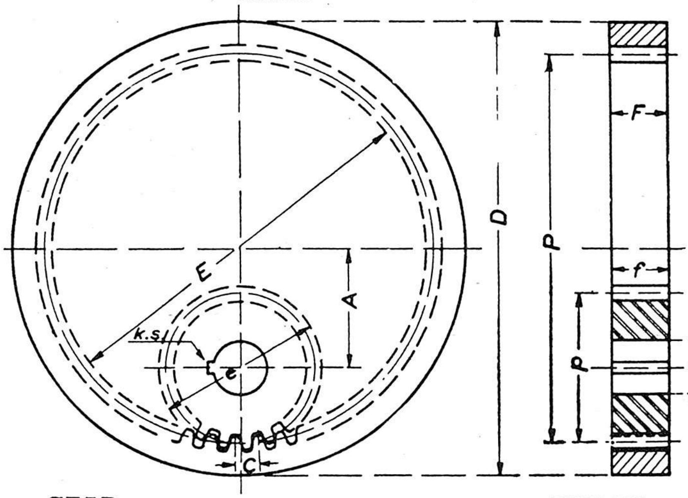
Module in Millimeters

Module, m/m	Corresponding English Diametral Pitch	Module, m/m	Corresponding English Diametral Pitch	Module, m/m	Corresponding English Diametral Pitch
0.5	50.800	2.75	9.236	8.	3.175
0.75	33.867	3.	8.466	9.	2.822
1.	25.400	3.5	7.257	10.	2.540
1.25	20.320	4.	6.350	11.	2.309
1.5	16.933	4.5	5.644	12.	2.117
1.75	14.514	5.	5.080	13.	1.954
2.	12.700	5.5	4.618	14.	1.814
2.25	11.288	6.	4.233	15.	1.693
2.5	10.160	7.	3.628	16.	1.587

FOOTE BROS. TABLE OF WORKING STRESSES USED FOR THE STRENGTH OF WORM GEARS

Velocity in feet Min. = V	$\frac{600}{600+V}$	Allowable Unit Stress at Given Velocity = S in pounds per sq. in.	
		Cast Iron	Phosphor Bronze
0	1.000	5300	8000
100	.857	4550	6800
200	.750	4000	6000
300	.666	3550	5350
450	.571	3000	4500
600	.500	2650	4000

INTERNAL GEARS



GEAR			PINION		
Number of Teeth.........	=		Number of Teeth.........	=	
Pitch....Circular........	=	C	Pitch....Circular.......	=	c
Pitch....Diameter.......	=	*	Pitch....Diameter......	=	*
Pitch Diameter...........	=	P	Pitch Diameter..........	=	p
Rim Diameter............	=	D	Outside Diameter........	=	e
Inside Diameter..........	=	E	Face....................	=	f
Face....................	=	F	Bore....................	=	b
Material................	=		Keyway..................	=	ks
....	=		Material................	=	

Distance between Centers........................ = A

When ordering, Internal Gears are the same as spur gears in regards to the number of teeth and pitch on pitch line. But you subtract two addendums or two teeth in place of adding as on spur gears for inside diameter.

Distance from end of teeth to plate or webb varies according to pitch and size of gear, from ¼ to 1 inch.

*Number of teeth to each inch of pitch diameter.

STRENGTH OF INTERNAL GEARS

In designing internal gears with which pinions or idlers are used, it is not necessary to calculate the strength of the internal gear or H. P. capacity because the pinion is always the weakest member if the two gears are made of the same material. This is due to the fact that the torque arm or lever of the internal gear is longer than the torque arm of the pinion and consequently the load on the teeth of the internal gear is less than on the pinion.

For theoretical purposes the strength of internal gear teeth can be calculated in approximately the same manner as ordinary external spur gears or racks.

It will be found that the strength of the internal gear tooth is greater than a rack tooth of the same pitch, pressure angle and depth of tooth. also that the strength increases as the number of teeth decreases. With an external gear the reverse is just the case, the tooth becomes weaker as teeth decrease in number.

The larger the number of teeth the more closely the internal gear tooth approaches that of a rack tooth consequently decreasing the strength.

DIAMETRAL AND CIRCULAR PITCH OF GEARS

Diametral Pitch	Circular Pitch, Inches	Diametral Pitch	Circular Pitch, Inches	Circular Pitch, Inches	Diametral Pitch	Circular Pitch, Inches	Diametral Pitch
1¼	2.5133	11	.286	2	1.571	¾	4.189
1½	2.0944	12	.262	1⅞	1.676	11/16	4.570
1¾	1.7952	14	.224	1¾	1.795	⅝	5.027
2	1.571	16	.196	1⅝	1.933	9/16	5.585
2¼	1.396	18	.175	1½	2.094	½	6.283
2½	1.257	20	.157	1 7/16	2.185	7/16	7.181
2¾	1.142	22	.143	1⅜	2.285	⅜	8.378
3	1.047	24	.131	1 5/16	2.394	5/16	10.053
3½	.898	26	.121	1¼	2.513	¼	12.566
4	.785	28	.112	1 3/16	2.646	3/16	16.755
5	.628	30	.105	1⅛	2.793	⅛	25.133
6	.524	32	.098	1 1/16	2.957	1/16	50.266
7	.449	36	.087	1	3.142	...	.....
8	.393	40	.079	15/16	3.351	...	.....
9	.349	48	.065	⅞	3.590	...	.....
10	.314			13/16	3.867	...	.....

SHOWING DEPTH OF SPACE AND THICKNESS OF TOOTH IN SPUR GEARS CUT WITH B. & S. MFGS. CUTTER

Pitch of Cutter	Depth to be Cut in Gear, Inches	Thickness of Tooth at Pitch Line, Inches	Pitch of Cutter	Depth to be Cut in Gear, Inches	Thickness of Tooth at Pitch Line, Inches
1¼	1.726	1.257	11	.196	.143
1½	1.438	1.047	12	.180	.131
1¾	1.233	.898	14	.154	.112
2	1.079	.785	16	.135	.098
2¼	.959	.698	18	.120	.087
2½	.863	.628	20	.108	.079
2¾	.784	.571	22	.098	.071
3	.719	.524	24	.090	.065
3½	.616	.449	26	.083	.060
4	.539	.393	28	.077	.056
5	.431	.314	30	.072	.052
6	.360	.262	32	.067	.049
7	.308	.224	36	.060	.044
8	.270	.196	40	.054	.039
9	.240	.175	48	.045	.033
10	.216	.157	....	.....	.....

Rules for Obtaining Ratio of the Gears Necessary to Cut a Given Spiral. Note the ratio of the required lead to 10. This ratio is the compound ratio of the driven to the driving gears. Example: If the lead of required spiral is 12 inches, 12 to 10 will be the ratio of the gears.

Or, divide the required lead by 10 and note the ratio between the quotient and 1. This ratio is usually the most simple form of the compound ratio of the driven to the driving gears. Example: If the required lead is 40 inches, the quotient is 40 ÷ 10 and the ratio 4 to 1.

TABLE FOR BLOCK OR MULTIPLE INDEXING

Teeth to be Cut	No. Indexed at Once	First Driver	First Follower	Second Driver	Second Follower	Turns of Locking Disc	Teeth to be Cut	No. Indexed at Once	First Driver	First Follower	Second Driver	Second Follower	Turns of Locking Disc
25	4	100	50	72	30	4	62	5	100	30	90	62	2
26	3	100	50	90	52	4	63	5	100	30	80	56	2
27	2	100	50	60	54	4	64	5	100	30	90	64	2
28	3	100	50	90	56	4	65	4	100	50	96	52	2
29	3	100	50	90	58	4	66	5	100	44	80	40	2
30	1	100	50	60	60	2	67	5	100	30	90	67	2
31	3	100	50	90	62	4	68	5	100	30	90	68	2
32	3	100	50	90	64	4	69	5	100	46	80	40	2
33	4	100	50	80	44	4	70	3	100	50	90	70	2
34	3	100	50	90	68	4	72	5	100	30	90	72	2
35	4	100	50	90	50	4	74	5	100	30	90	74	2
36	5	100	48	80	40	4	75	7	100	30	84	50	2
37	5	100	30	90	74	4	76	5	100	30	90	76	2
38	5	100	30	90	76	4	77	4	100	70	96	44	2
39	5	100	30	90	78	4	78	5	100	30	90	78	2
40	3	100	50	90	80	4	80	3	100	50	90	80	2
41	5	100	30	90	82	4	81	7	100	30	84	52	2
42	5	100	30	90	84	4	82	5	100	30	90	82	2
43	5	100	30	90	86	4	84	5	100	30	90	84	2
44	5	100	30	90	88	4	85	4	100	50	96	68	2
45	7	100	50	70	30	4	86	5	100	30	90	86	2
46	5	100	30	90	92	4	87	7	100	30	84	58	2
47	5	100	30	90	94	4	88	5	100	30	90	88	2
48	5	100	30	90	96	4	90	7	100	30	70	50	2
49	5	100	30	90	98	4	91	3	100	70	72	52	2
50	7	100	50	84	40	4	92	5	100	30	90	92	2
51	4	100	30	96	68	2	93	7	100	30	84	62	2
52	5	100	30	90	52	2	94	5	100	30	90	94	2
54	5	100	30	90	54	2	95	4	100	50	96	76	2
55	4	100	50	96	44	2	96	5	100	30	90	96	2
56	5	100	30	90	56	2	98	5	100	30	90	98	2
57	4	100	30	96	70	2	99	10	100	30	80	44	2
58	5	100	30	90	58	2	100	7	100	50	84	40	2
60	7	100	30	84	40	2	102	5	100	30	60	68	2

BRICKWORK

Brickwork is estimated by the thousand, and of various thicknesses of wall, runs as follows:

$8\frac{1}{4}$ inch Wall, or 1 Brick in thickness, 14 Bricks per superficial foot

$12\frac{3}{4}$ inch Wall, or $1\frac{1}{2}$ Brick in thickness, 21 Bricks per superficial foot

17 inch Wall, or 2 Brick in thickness, 28 Bricks per superficial foot

$21\frac{1}{2}$ inch Wall, or $2\frac{1}{2}$ Brick in thickness, 35 Bricks per superficial foot

An ordinary Brick measures about $8\frac{1}{4}$ x 4 x 2 inches, which is equal to 66 cubic inches or 26.2 Bricks to a cubic foot. The average weight is $4\frac{1}{2}$ lbs.

ANGLES TO SET INDEX HEAD OF MILLING MACHINE WHEN CUTTING CLUTCHES WITH ANGULAR CUTTERS

No. of Teeth	Angle of Cutter			No. of Teeth	Angle of Cutter		
	60°	70°	80°		60°	70°	80°
5			82° 12′	18	84° 9′	86° 19′	88° 13′
6		77° 52′	84° 9′	19	84° 30′	86° 31′	88° 19′
7	73° 50′	79° 54′	85° 10′	20	84° 46′	86° 42′	88° 24′
8	76° 10′	81° 20′	85° 48′	21	85° 1′	86° 51′	88° 29′
9	77° 52′	82° 23′	86° 19′	22	85° 13′	87° 00′	88° 33′
10	79° 12′	83° 13′	86° 43	23	85° 27′	87° 8′	88° 37′
11	80° 14′	83° 54′	87° 4′	24	85° 38′	87° 15′	88° 40′
12	81° 6′	84° 24′	87° 18′	25	85° 49′	87° 22′	88° 43′
13	81° 49′	84° 51′	87° 30′	26	85° 59′	87° 28′	88° 46′
14	82° 26′	85° 12′	87° 42′	27	86° 8′	87° 34′	88° 50′
15	82° 57′	85° 34′	87° 51′	28	86° 16′	87° 39′	88° 52′
16	83° 24′	85° 51′	87° 59′	29	86° 24′	87° 44′	88° 54′
17	83° 48′	86° 6′	88° 7	30	86° 31′	87° 48′	88° 56′

TABLE FOR OBTAINING SET-OVER FOR CUTTING BEVEL GEARS

Ratio of Apex Distance to Width of Face—$\frac{\text{Face}}{\text{Apex}}$

No. of Cutter	3/1	3¼/1	3½/1	3¾/1	4/1	4¼/1	4½/1	4¾/1	5/1	5½/1	6/1	7/1	8/1
1	.254	.254	.255	.256	.257	.257	.257	.258	.258	.259	.260	.262	.264
2	.266	.268	.271	.272	.273	.274	.274	.275	.277	.279	.280	.283	.284
3	.266	.268	.271	.273	.275	.278	.280	.282	.283	.286	.287	.290	.292
4	.275	.280	.285	.287	.291	.293	.296	.298	.298	.302	.305	.308	.311
5	.280	.285	.290	.293	.295	.296	.298	.300	.302	.307	.309	.313	.315
6	.311	.318	.323	.328	.330	.334	.337	.340	.343	.348	.352	.356	.362
7	.289	.298	.308	.316	.324	.329	.334	.338	.343	.350	.360	.370	.376
8	.275	.286	.296	.309	.319	.331	.338	.344	.352	.361	.368	.380	.386

TO SHARPEN REAMERS.

Hand Reamers, when dull through wear, should be stoned first on the face of the flutes then on top of the flutes. The stone should always be held perfectly flat with the face and clearance that the original shape of the flutes may be preserved.

The Norton Co. make a Stone which is adapted for the purpose, and gives quicker results than any oil stone. The stone should be kept clean by the use of turpentine.

End Cutting Reamers should be first ground on centres with a wheel, and then recleared to insure reaming a hole the same size of Reamer.

TABLE OF APPROXIMATE ANGLES FOR CUTTING SPIRALS

TANGENT OF ANGLE OF SPIRAL $= \dfrac{\text{CIRCUMFERENCE OF CUTTER, DRILL, OR MILL}}{\text{LEAD IN INCHES TO ONE TURN}}$

C = CIRCUMFERENCE OF CUTTER, DRILL, OR MILL
L = LEAD IN INCHES TO ONE TURN
T = TANGENT OF ANGLE OF SPIRAL

$T = \dfrac{C}{L}$ $L = \dfrac{C}{T}$

NOS. OF TEETH IN GEARS FURNISHED WITH MACHINE
24(2) 28 32 40 44 48 56 64 72 86 100

THE LEAD IN INCHES TO ONE TURN $= \dfrac{\text{10 X GEAR ON WORM X 2ND GEAR ON STUD}}{\text{GEAR ON SCREW X 1ST GEAR ON STUD}}$

DIAMETER OF CUTTER, DRILL, OR MILL

Gear on Worm	1st Gear on Stud	2nd Gear on Stud	Gear on Screw	Lead in Inches to One Turn	1/8"	1/4"	3/8"	1/2"	5/8"	3/4"	7/8"	1"	1¼"	1½"	1¾"	2"	2¼"	2½"	2¾"	3"	3¼"	3½"	3¾"	4"	4¼"	4½"	4¾"	5"	5¼"	5½"	5¾"	6"
24	72	28	86	1.085	20	36	47¼																									
24	72	32	86	1.240	17½	32¼	43½	51¾																								
24	72	40	100	1.333	16½	30½	41½	49¾																								
24	48	28	100	1.400	15¾	29¼	40	48¼																								
24	64	40	100	1.500	14¾	27¾	38¼	46¼	52½																							
28	56	32	100	1.600	13¾	26¼	36¼	44½	50¾																							
24	72	44	86	1.706	13	24¾	34½	42½	49																							
24	64	48	100	1.800	12¼	23½	33¼	41	47½	52½																						
24	40	32	100	1.920	11½	22¼	31½	39¼	45¾	50¾																						
28	64	40	86	2.035	11	21	30	37¾	44	49¼																						
24	72	56	86	2.171	10¼	20	28½	35¾	42	47¼	51¾																					
24	64	44	72	2.292	9¾	19	27¼	34½	40½	45¾	50¼																					
28	64	56	100	2.450	9	17¾	25¾	32¾	38¾	44	48¼	52																				
40	86	56	100	2.605	8½	16¾	24¼	31	37	42	46½	50¼																				
40	56	28	72	2.778	8	15¾	23	29½	35¼	40¼	44¾	48½																				
24	56	44	64	2.946	7½	15	21¾	28	33¾	38¾	43	46¾																				
24	86	72	64	3.140	7	14	20½	26½	32	37	41¼	45	51¼																			
28	56	48	72	3.333	6¾	13¼	19½	25¼	30½	35¼	39½	43¼	49¾																			
48	44	28	86	3.552	6¼	12½	18¼	23¾	29	33½	37¾	41½	47¾	53																		
44	56	48	100	3.771	6	11¾	17¼	22½	27½	32	36	39¾	46¼	51¼																		
72	100	48	86	4.019	5½	11	16¼	21¼	26	30½	34¼	38	44¼	49½																		
64	48	32	100	4.267	5¼	10½	15½	20¼	24¾	29	32¾	36¼	42½	47¾	52¼																	
56	48	28	72	4.537	5	9¾	14½	19	23½	27½	31¼	34¾	41	46	50½																	
56	64	40	72	4.861	4½	9¼	13½	18	22	25¾	29½	32¾	39	44	48½	52¼																

EXAMPLE ILLUSTRATING USE OF TABLE

DIAMETER OF CUTTER, DRILL, OR MILL.......... = 1¼
LEAD IN INCHES TO ONE TURN.................. = 3.140
REQUIRED ANGLE TO NEAREST QUARTER DEGREE TO SET SADDLE OF UNIVERSAL MILLING MACHINE = 51¼°

Continued on next page

TABLE OF APPROXIMATE ANGLES FOR CUTTING SPIRALS

$$\text{TANGENT OF ANGLE OF SPIRAL} = \frac{\text{CIRCUMFERENCE OF CUTTER, DRILL, OR MILL}}{\text{LEAD IN INCHES TO ONE TURN}}$$

C = CIRCUMFERENCE OF CUTTER, DRILL, OR MILL
L = LEAD IN INCHES TO ONE TURN
T = TANGENT OF ANGLE OF SPIRAL

$$T = \frac{C}{L} \qquad L = \frac{C}{T}$$

NOS. OF TEETH IN GEARS FURNISHED WITH MACHINE
24(2) 28 32 40 44 48 56 64 72 86 100

$$\text{THE LEAD IN INCHES TO ONE TURN} = \frac{10 \times \text{GEAR ON WORM} \times \text{2ND GEAR ON STUD}}{\text{GEAR ON SCREW} \times \text{1ST GEAR ON STUD}}$$

DIAMETER OF CUTTER, DRILL, OR MILL

Gear on Worm	1st Gear on Stud	2nd Gear on Stud	Gear on Screw	Lead in Inches to One Turn	⅛"	¼"	⅜"	½"	⅝"	¾"	⅞"	1"	1¼"	1½"	1¾"	2"	2¼"	2½"	2¾"	3"	3¼"	3½"	3¾"	4"	4¼"	4½"	4¾"	5"	5¼"	5½"	5¾"	6"
56	48	44	100	5.133	4¼	8¾	13	17	21	24¾	28¼	31½	37½	42½	47	50¾																
86	44	28	100	5.473	4	8¼	12¼	16	19¾	23¼	26¾	29¾	35¾	40¾	45	49	52¼															
100	48	24	86	5.814	3¾	7¾	11½	15	18¾	22	25¼	28½	34	39	43½	47¼	50½															
72	56	48	100	6.171	3¾	7¼	10¾	14¼	17¾	21	24	27	32½	37¼	41¾	45½	48¾	51¾														
72	56	44	86	6.578	3½	6¾	10¼	13½	16½	19¾	22¾	25½	30¾	35½	40	43¾	47	50	52¾													
56	32	40	100	7.000	3¼	6½	9½	12¾	15¾	18½	21½	24¼	29¼	34	38¼	42	45¼	48¼	51													
56	28	32	86	7.442	3	6	9	12	14¾	17½	20¼	23	27¾	32¼	36½	40¼	43½	46½	49¼	51¾												
72	40	44	100	7.920	2¾	5¾	8½	11¼	14	16½	19¼	21¾	26¼	30¾	34¾	38½	41¾	44¾	47½	50	52¼											
56	32	48	100	8.400	2¾	5¼	8	10½	13¼	15¾	18	20½	25	29¼	33¼	36¾	40	43	45¾	48¼	50½	52½										
86	32	24	72	8.959	2½	5	7½	10	12¼	14¾	17	19¼	23¾	27¾	31½	35	38¼	41¼	44	46½	48¾	50¾	52¾									
64	48	40	56	9.524	2¼	4¾	7	9¼	11¾	14	16	18¼	22½	26¼	30	33½	36½	39½	42¼	44¾	47	49	51	52¾								
100	44	32	72	10.101	2¼	4½	6¾	8¾	11	13	15¼	17¼	21¼	25	28½	31¾	35	37¾	40½	43	45¼	47½	49½	51¼	53							
86	40	32	64	10.750	2	4¼	6¼	8¼	10¼	12¼	14¼	16¼	20	23¾	27	30¼	33¼	36¼	38¾	41¼	43½	45¾	47½	49½	51¼	52¾						
86	48	64	100	11.467	2	4	5¾	7¾	9¾	11½	13½	15¼	19	22¼	25½	28¾	31¾	34½	37	39½	41¾	43¾	45¾	47½	49¼	51	52½					
72	44	64	86	12.178	1¾	3¾	5½	7¼	9¼	11	12¾	14½	18	21¼	24¼	27¼	30¼	32¾	35¼	37¾	40	42	44	46	47¾	49¼	50¾	52¼				
56	24	40	72	12.963	1¾	3½	5¼	7	8½	10¼	12	13½	16¾	20	23	25¾	28½	31¼	33¾	36	38¼	40¼	42¼	44	45¾	47½	49	50½	51½	51¾		
86	40	64	100	13.760	1¾	3¼	5	6½	8	9¾	11¼	12¾	16	19	21¾	24½	27¼	29¾	32	34½	36½	38½	40½	42½	44¼	45¾	47¼	48¾	50¼	51½	52¾	
86	44	48	64	14.659	1½	3	4½	6	7¾	9¼	10½	12	15	17¾	20½	23¼	25¾	28¼	30½	32¾	34¾	36¾	38¾	40½	42¼	44	45½	47	48¼	49¾	51	52
64	32	56	72	15.556	1½	3	4¼	5¾	7¼	8½	10	11½	14¼	16¾	19½	22	24½	26¾	29	31¼	33¼	35¼	37¼	39	40¾	42¼	43¾	45¼	46¾	48	49¼	50½
72	40	44	48	16.500	1¼	2¾	4	5½	6¾	8¼	9½	10¾	13½	16	18½	20¾	23¼	25½	27¾	29¾	31¾	33¾	35½	37¼	39	40½	42	43½	45	46¼	47½	48¾
100	44	56	72	17.677	1¼	2½	3¾	5	6¼	7½	8¾	10	12½	15	17¼	19½	21¾	24	26	28	30	31¾	33¾	35½	37	38¾	40¼	41½	43	44¼	45½	46¾
86	28	44	72	18.770	1¼	2½	3½	4¾	6	7¼	8¼	9½	11¾	14	16¼	18½	20¾	22¾	24¾	26¾	28½	30¼	32	33¾	35½	37	38½	40	41¼	42½	44	45
100	28	48	86	19.934	1¼	2¼	3½	4½	5½	6¾	7¾	9	11¼	13¼	15½	17½	19½	21½	23½	25¼	27	28¾	30½	32¼	33¾	35¼	36¾	38¼	39½	41	42¼	43½
86	32	44	56	21.12	1	2¼	3¼	4¼	5¼	6¼	7½	8½	10½	12½	14½	16½	18½	20½	22¼	24	25¾	27½	29¼	30¾	32¼	33¾	35¼	36¾	38	39¼	40½	41¾

Continued on next page

TABLE OF APPROXIMATE ANGLES FOR CUTTING SPIRALS

$$\text{TANGENT OF ANGLE OF SPIRAL} = \frac{\text{CIRCUMFERENCE OF CUTTER, DRILL, OR MILL}}{\text{LEAD IN INCHES TO ONE TURN}}$$

C = CIRCUMFERENCE OF CUTTER, DRILL, OR MILL
L = LEAD IN INCHES TO ONE TURN
T = TANGENT OF ANGLE OF SPIRAL

$$T = \frac{C}{L} \qquad L = \frac{C}{T}$$

NOS. OF TEETH IN GEARS FURNISHED WITH MACHINE
24(2) 28 32 40 44 48 56 64 72 86 100

$$\text{THE LEAD IN INCHES TO ONE TURN} = \frac{10 \times \text{GEAR ON WORM} \times \text{2ND GEAR ON STUD}}{\text{GEAR ON SCREW} \times \text{1ST GEAR ON STUD}}$$

DIAMETER OF CUTTER, DRILL, OR MILL

Gear on Worm	1st Gear on Stud	2nd Gear on Stud	Gear on Screw	Lead in Inches to One Turn	⅛"	¼"	⅜"	½"	⅝"	¾"	⅞"	1"	1¼"	1½"	1¾"	2"	2¼"	2½"	2¾"	3"	3¼"	3½"	3¾"	4"	4¼"	4½"	4¾"	5"	5¼"	5½"	5¾"	6"
72	28	56	64	22.50	1	2	3	4	5	6	7	8	10	11¾	13¾	15½	17½	19¼	21	22¾	24½	26	27¾	29¼	30¾	32¼	33½	35	36¼	37½	38¾	40
64	40	72	48	24.00	1	2	2¾	3¾	4¾	5½	6½	7½	9¼	11	13	14¾	16½	18¼	19¾	21½	23	24½	26¼	27½	29	30½	31¾	33¼	34½	35¾	37	38¼
100	64	72	44	25.57	1	1¾	2¾	3½	4½	5¼	6¼	7¼	8¾	10½	12¼	13¾	15½	17	18¾	20¼	21¾	23¼	24¾	26¼	27½	29	30¼	31½	32¾	34	35¼	36½
100	72	86	44	27.15		1¾	2½	3¼	4¼	5	5¾	6½	8¼	9¾	11½	13	14½	16¼	17¾	19¼	20½	22	23½	24¾	26¼	27½	28¾	30	31¼	32½	33¾	34¾
86	40	64	48	28.67		1½	2¼	3¼	4	4¾	5½	6¼	7¾	9¼	10¾	12¼	13¾	15¼	16¾	18¼	19½	21	22¼	23¾	25	26¼	27½	28¾	30	31	32¼	33¼
86	32	64	56	30.71		1½	2¼	3	3¾	4½	5	5¾	7¼	8¾	10¼	11½	13	14¼	15¾	17	18½	19¾	21	22¼	23½	24¾	26	27	28¼	29¼	30½	31½
72	32	64	44	32.73		1¼	2	2¾	3½	4	4¾	5½	6¾	8¼	9½	10¾	12¼	13½	14¾	16	17¼	18½	19¾	21	22¼	23¼	24½	25¾	26¾	27¾	29	30
100	24	40	48	34.72		1¼	2	2½	3¼	4	4½	5¼	6½	7¾	9	10¼	11½	12¾	14	15¼	16½	17½	18¾	20	21	22¼	23¼	24¼	25½	26½	27½	28½
100	24	64	72	37.04		1¼	1¾	2½	3	3¾	4¼	4¾	6	7¼	8½	9¾	10¾	12	13¼	14¼	15½	16½	17¾	18¾	19¾	21	22	23	24	25	26	27
100	28	44	40	39.29		1¼	1¾	2¼	2¾	3½	4	4½	5¾	6¾	8	9	10¼	11¼	12½	13½	14½	15¾	16¾	17¾	18¾	19¾	20¾	21¾	22¾	23¾	24¾	25½
86	24	56	48	41.81		1	1½	2¼	2¾	3¼	3¾	4¼	5¼	6½	7½	8½	9½	10¾	11¾	12¾	13¾	14¾	15¾	16¾	17¾	18¾	19¾	20½	21½	22½	23¼	24¼
100	28	40	32	44.64		1	1½	2	2½	3	3½	4	5	6	7	8	9	10	11	12	13	13¾	14¾	15¾	16¾	17½	18½	19½	20¼	21¼	22	23
100	28	64	48	47.62		1	1½	2	2¼	2¾	3¼	3¾	4¾	5¾	6½	7½	8½	9¼	10¼	11¼	12	13	14	14¾	15¾	16½	17½	18¼	19	20	20¾	21½
86	28	72	44	50.26		1	1¼	1¾	2¼	2¾	3¼	3½	4½	5¼	6¼	7¼	8	9	9¾	10½	11½	12¼	13¼	14	14¾	15¾	16½	17¼	18¼	19	19¾	20½
100	28	48	32	53.57			1¼	1¾	2	2½	3	3¼	4½	5	5¾	6¾	7	8¼	9¼	10	10¾	11½	12½	13¼	14	14¾	15½	16¼	17	17¾	18¾	19½
100	28	64	40	57.14			1¼	1½	2	2¼	2¾	3¼	4	4¾	5½	6¼	7	7¾	8½	9¼	10¼	11	11¾	12½	13¼	14	14¾	15¼	16	16¾	17½	18¼
100	24	64	44	60.61			1	1½	1¾	2¼	2½	3	3¾	4½	5¼	6	6¾	7½	8	8¾	9½	10¼	11	11¾	12½	13	13¾	14½	15¼	16	16½	17¼
100	28	86	48	63.99				1½	1¾	2	2½	2¾	3½	4¼	5	5½	6¼	7	7¾	8½	9	9¾	10½	11	11¾	12½	13	13¾	14½	15	15¾	16½
72	24	64	28	68.57				1¼	1¾	2	2¼	2½	3¼	4	4½	5¼	6	6½	7¼	7¾	8½	9	9¾	10½	11	11¾	12¼	13	13½	14¼	14¾	15¼
86	24	64	32	71.67				1¼	1½	2	2¼	2½	3¼	3¾	4½	5	5¾	6¼	6¾	7½	8	8¾	9¼	10	10½	11¼	11¾	12¼	13	13½	14¼	14¾
100	24	72	40	75.00				1¼	1½	1¾	2	2½	3	3½	4¼	4¾	5½	6	6½	7¼	7¾	8¼	9	9½	10	10¾	11¼	11¾	12½	13	13½	14
100	24	64	32	83.33				1	1¼	1½	2	2¼	2¾	3¼	3¾	4¼	4¾	5½	6	6½	7	7½	8	8½	9	9½	10¼	10¾	11¼	11¾	12¼	12¾
100	24	86	40	89.59				1	1¼	1½	1¾	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
100	24	64	28	95.24					1¼	1½	1¾	2	2¼	2¾	3¼	3¾	4¼	4¾	5¼	5¾	6	6½	7	7½	8	8½	9	9¼	9¾	10¼	10¾	11¼

Double Compounding of Gearing, or the Use of Six Change Gears. In milling machine work, it is often necessary to obtain longer or more accurate leads than are possible by the use of four change gears. Therefore, the table of gear ratios on the opposite page is given to supplement the ordinary table of leads and permit the quick selection of the other two change gears.

The table of gear ratios is based upon the change gears furnished with Brown & Sharpe Universal Milling Machines. These change gears are as follows: 24 (2), 28, 32, 40, 44, 48, 56, 64, 72, 86, 100. Occasionally in determining the most accurate lead, the proper change gears will necessitate the use of two gears with the same number of teeth. Inasmuch as there are no two gears with the same number of teeth (with the exception of two gears with 24 teeth) it will be necessary to employ the next nearest gear ratio, resulting in a lead very close to the one desired.

Determining the Proper Change Gears to Use when Six Change Gears are Necessary.

Example: To find the proper change gears for gashing a hob with a lead of 167.5″.

Referring to the Table of Leads we find that 149.31″ is the longest obtainable with four regular change gears. Assuming that a greater degree of accuracy is desired, divide the lead desired (167.5) by the decimal equivalent 4.1667 given in the table on the opposite page and we have 40.1997″. The decimal equivalent 4.1667 is taken, as it corresponds to the first gear ratio (100 : 24) given for lead 149.31″ in the table of leads. The nearest lead to 40.1997 (which was found above) listed in the table of leads is 40.18″. Inasmuch as two 100 tooth gears are required to obtain this lead, it is necessary to try the next gear ratio.

Dividing 167.5 by 3.5833 (the decimal equivalent of the next ratio), we have 46.7446. Referring to the Table of Leads it will be found that the nearest lead is 46.67, for which the change gears are $\frac{64}{24}$ and $\frac{56}{32}$.

Adding the two gears from the Table of Ratios and to the driven gears the constant 10 (which is the constant of the lead of the machine), we have

$$\frac{64 \times 56 \times \mathbf{86} \times 10}{24 \times 32 \times \mathbf{24}} = 167.2222$$

Continued

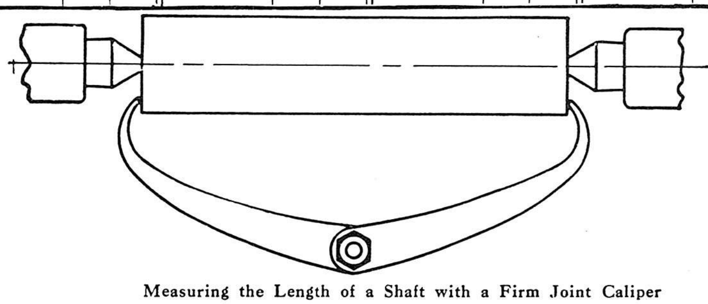
Thus the six change gears 64, 24, 56, 32, 86 and 24 will give a lead of 167.2222. The error of lead .2778″ or the difference between the lead desired and the lead obtained is for this length of lead practically negligible and is considered near enough for all practical purposes.

TABLE OF RATIOS OF TWO GEARS WITH THEIR DECIMAL EQUIVALENTS

RATIO	DEC. EQUIV.	RATIO	DEC. EQUIV.	RATIO	DEC. EQUIV.
100:24	4.1667	100:72	1.3889	28:40	.7000
86:24	3.5833	44:32	1.3750	44:64	.6875
100:28	3.5714	86:64	1.3438	48:72	.6667
100:32	3.1250	64:48	1.3333	32:48	.6667
86:28	3.0714	32:24	1.3333	56:86	.6512
72:24	3.0000	72:56	1.2857	64:100	.6400
86:32	2.6875	56:44	1.2727	28:44	.6364
64:24	2.6667	40:32	1.2500	40:64	.6250
72:28	2.5714	48:40	1.2000	44:72	.6111
100:40	2.5000	86:72	1.1944	24:40	.6000
56:24	2.3333	56:48	1.1667	28:48	.5833
64:28	2.2857	28:24	1.1667	32:56	.5714
100:44	2.2727	100:86	1.1628	56:100	.5600
72:32	2.2500	64:56	1.1429	48:86	.5581
86:40	2.1500	32:28	1.1429	40:72	.5556
100:48	2.0833	72.64	1.1250	24:44	.5455
48:24	2.0000	44:40	1.1000	44:86	.5116
56:28	2.0000	48:44	1.0909	24:48	.5000
64:32	2.0000	44:48	.9167	28:56	.5000
86:44	1.9545	40:44	.9091	32:64	.5000
44:24	1.8333	64:72	.8889	48:100	.4800
72:40	1.8000	56:64	.8750	40:86	.4651
86:48	1.7917	28:32	.8750	32:72	.4444
100:56	1.7857	86:100	.8600	44:100	.4400
56:32	1.7500	48:56	.8571	28:64	.4375
48:28	1.7143	24:28	.8571	24:56	.4286
40:24	1.6667	72:86	.8372	40:100	.4000
72:44	1.6364	40:48	.8333	28:72	.3889
64:40	1.6000	32:40	.8000	24:64	.3750
44:28	1.5714	44:56	.7857	32:86	.3721
100:64	1.5625	56:72	.7778	24:72	.3333
86:56	1.5357	24:32	.7500	28:86	.3256
48:32	1.5000	48:64	.7500	32:100	.3200
72:48	1.5000	64:86	.7442	28:100	.2800
64:44	1.4545	32:44	.7273	24:86	.2791
40:28	1.4286	72:100	.7200	24:100	.2400
56:40	1.4000	40:56	.7143		

INDEX MOVEMENTS OF SPIRAL HEAD
FOR
LONGITUDINAL GRADUATING ON A MILLING MACHINE

Movement of Table	Holes	Circle	Movement of Table	Holes	Circle	Movement of Table	Holes	Circle	Movement of Table	Holes	Circle
.0001275	1	49	.0006377	5	49	.0011479	9	49	.0016447	5	19
.0001330	1	47	.0006410	4	39	.0011574	5	27	.0016581	13	49
.0001454	1	43	.0006465	3	29	.0011628	8	43	.0016666	4	15
.0001524	1	41	.0006579	2	19	.0011718	3	16	.0016768	11	41
.0001603	1	39	.0006649	5	47	.0011824	7	37	.0016892	10	37
.0001689	1	37	.0006757	4	37	.0011905	4	21	.0017045	9	33
.0001894	1	33	.0006944	3	27	.0011968	9	47	.0017241	8	29
.0002016	1	31	.0006944	2	18	.0012096	6	31	.0017288	13	47
.0002155	1	29	.0007268	5	43	.0012195	8	41	.0017361	5	18
.0002315	1	27	.0007353	2	17	.0012500	4	20	.0017442	12	43
.0002551	2	49	.0007576	4	33	.0012500	3	15	.0017628	11	39
.0002660	2	47	.0007622	5	41	.0012755	10	49	.0017857	6	21
.0002717	1	23	.0007653	6	49	.0012820	8	39	.0017857	14	49
.0002907	2	43	.0007813	2	16	.0012930	6	29	.0018144	9	31
.0002976	1	21	.0007979	6	47	.0013081	9	43	.0018292	12	41
.0003049	2	41	.0008012	5	39	.0013158	4	19	.0018382	5	17
.0003125	1	20	.0008064	4	31	.0013257	7	33	.0018518	8	27
.0003205	2	39	.0008152	3	23	.0013298	10	47	.0018581	11	37
.0003289	1	19	.0008333	2	15	.0013513	8	37	.0018617	14	47
.0003378	2	37	.0008446	5	37	.0013587	5	23	.001875	6	20
.0003472	1	18	.0008621	4	29	.0013722	9	41	.0018896	13	43
.0003676	1	17	.0008721	6	43	.0013888	6	27	.0018939	10	33
.0003788	2	33	.0008929	7	49	.0013888	4	18	.0019021	7	23
.0003826	3	49	.0008929	3	21	.0014031	11	49	.0019132	15	49
.0003906	1	16	.0009146	6	41	.0014113	7	31	.0019231	12	39
.0003989	3	47	.0009259	4	27	.0014422	9	39	.0019396	9	29
.0004032	2	31	.0009308	7	47	.0014535	10	43	.0019532	5	16
.0004167	1	15	.0009375	3	20	.0014628	11	47	.0019737	6	19
.0004310	2	29	.0009469	5	33	.0014706	4	17	.0019818	13	41
.0004361	3	43	.0009616	6	39	.0014881	5	21	.0019947	15	47
.0004573	3	41	.0009869	3	19	.0015086	7	29	.0020161	10	31
.0004630	2	27	.0010081	5	31	.0015152	8	33	.0020271	12	37
.0004808	3	39	.0010136	6	37	.0015202	9	37	.002035	14	43
.0005068	3	37	.0010174	7	43	.0015244	10	41	.0020485	16	49
.0005102	4	49	.0010204	8	49	.0015306	12	49	.0020833	13	39
.0005319	4	47	.0010417	3	18	.0015625	5	20	.0020833	5	15
.0005435	2	23	.0010638	8	47	.0015625	4	16	.0020833	11	33
.0005682	3	33	.0010671	7	41	.0015957	12	47	.0020833	9	27
.0005814	4	43	.0010776	5	29	.0015989	11	43	.0020833	7	21
.0005952	2	21	.0010869	4	23	.0016026	10	39	.0020833	6	18
.0006048	3	31	.0011029	3	17	.0016128	8	31	.0021277	16	47
.0006098	4	41	.0011218	7	39	.0016204	7	27	.0021342	14	41
.0006250	2	20	.0011363	6	33	.0016303	6	23	.0021552	10	29



Measuring the Length of a Shaft with a Firm Joint Caliper

INDEX MOVEMENTS OF SPIRAL HEAD
FOR
LONGITUDINAL GRADUATING ON A MILLING MACHINE

Movement of Table	Holes	Circle	Movement of Table	Holes	Circle	Movement of Table	Holes	Circle	Movement of Table	Holes	Circle
.0021682	17	49	.0026785	9	21	.0032014	21	41	.003699	29	49
.0021738	8	23	.0026785	21	49	.003205	20	39	.0037038	16	27
.0021802	15	43	.0027028	16	37	.0032095	19	37	.0037163	22	37
.0021875	7	20	.0027174	10	23	.0032197	17	33	.0037234	28	47
.002196	13	37	.0027243	17	39	.0032257	16	31	.003750	12	20
.0022059	6	17	.0027344	7	16	.0032327	15	29	.003750	9	15
.0022176	11	31	.002744	18	41	.0032408	14	27	.0037793	26	43
.0022436	14	39	.0027618	19	43	.0032607	12	23	.0037878	20	33
.0022607	17	47	.0027777	8	18	.0032738	11	21	.0038043	14	23
.0022728	12	33	.0027777	12	27	.0032895	10	19	.0038112	25	41
.0022866	15	41	.0027925	21	47	.0033088	9	17	.0038195	11	18
.0022959	18	49	.0028017	13	29	.0033164	26	49	.0038265	30	49
.0023027	7	19	.002806	22	49	.0033245	25	47	.0038305	19	31
.0023148	10	27	.0028125	9	20	.0033333	8	15	.003846	24	39
.0023257	16	43	.0028225	14	31	.0033431	23	43	.0038564	29	47
.0023438	6	16	.0028409	15	33	.0033538	22	41	.0038692	13	21
.0023649	14	37	.0028717	17	37	.0033654	21	39	.0038794	18	29
.0023706	11	29	.0028846	18	39	.0033784	20	37	.0038853	23	37
.0023809	8	21	.0028963	19	41	.0034091	18	33	.0039063	10	16
.0023937	18	47	.002907	20	43	.0034273	17	31	.0039246	27	43
.0024038	15	39	.0029167	7	15	.0034375	11	20	.0039352	17	27
.0024192	12	31	.0029256	22	47	.0034439	27	49	.0039475	12	19
.0024235	19	49	.0029337	23	49	.0034482	16	29	.003954	31	49
.0024306	7	18	.0029412	8	17	.0034574	26	47	.0039636	26	41
.002439	16	41	.0029605	9	19	.0034722	10	18	.0039773	21	33
.0024455	9	23	.0029762	10	21	.0034722	15	27	.0039894	30	47
.0024622	13	33	.002989	11	23	.0034885	24	43	.0040064	25	39
.002471	17	43	.0030094	13	27	.0035063	23	41	.0040322	20	31
.00250	8	20	.0030172	14	29	.0035156	9	16	.0040443	11	17
.00250	6	15	.0030241	15	31	.0035255	22	39	.0040541	24	37
.0025266	19	47	.0030303	16	33	.0035325	13	23	.0040625	13	20
.0025339	15	37	.0030406	18	37	.0035474	21	37	.00407	28	43
.0025463	11	27	.0030448	19	39	.0035714	12	21	.0040759	15	23
.002551	20	49	.0030488	20	41	.0035714	28	49	.0040817	32	49
.002564	16	39	.0030524	21	43	.0035904	27	47	.0040948	19	29
.0025736	7	17	.0030586	23	47	.0035984	19	33	.004116	27	41
.0025862	12	29	.0030611	24	49	.0036186	11	19	.0041223	31	47
.0025915	17	41	.003125	9	18	.0036289	18	31	.0041666	22	33
.0026164	18	43	.003125	10	20	.0036339	25	43	.0041666	14	21
.0026209	13	31	.003125	8	16	.0036585	24	41	.0041666	18	27
.0026316	8	19	.0031889	25	49	.0036637	17	29	.0041666	12	18
.0026515	14	33	.0031915	24	47	.0036765	10	17	.0041666	10	15
.0026596	20	47	.0031978	22	43	.0036858	23	39	.0041666	26	39

Formed Threading Tool

A formed threading tool is sometimes used if considerable threading is to be done. Fig. 1 illustrates a good type of formed threading tool. The formed threading tool requires grinding on top only to sharpen, and therefore always remains true to form and correct angle.

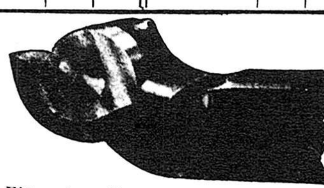


Fig. 1 Formed Thread Cutting Tool, Solid Type

INDEX MOVEMENTS OF SPIRAL HEAD
FOR
LONGITUDINAL GRADUATING ON A MILLING MACHINE

Movement of Table	Holes	Circle	Movement of Table	Holes	Circle	Movement of Table	Holes	Circle	Movement of Table	Holes	Circle
.0042091	33	49	.0047256	31	41	.0052327	36	43	.0057433	34	37
.0042152	29	43	.0047299	28	37	.0052365	31	37	.0057692	36	39
.0042232	25	37	.0047349	25	33	.0052419	26	31	.0057874	25	27
.0042338	21	31	.0047414	22	29	.0052635	16	19	.0057927	38	41
.0042553	32	47	.004762	16	21	.0052884	33	39	.0058142	40	43
.0042685	28	41	.0047796	13	17	.005303	28	33	.0058187	27	29
.0042765	13	19	.0047873	36	47	.0053125	17	20	.0058336	14	15
.0042971	11	16	.0047968	33	43	.0053194	40	47	.0058466	29	31
.0043104	20	29	.0048074	30	39	.0053242	23	27	.0058512	44	47
.0043268	27	39	.0048384	24	31	.0053364	35	41	.0058599	15	16
.0043368	34	49	.004847	38	49	.0053572	42	49	.0058674	46	49
.0043477	16	23	.0048613	14	18	.0053572	18	21	.005871	31	33
.0043562	23	33	.0048613	21	27	.0053781	37	43	.0058825	16	17
.0043605	30	43	.0048782	32	41	.005388	25	29	.0059027	17	18
.004375	14	20	.0048912	18	23	.0054057	32	37	.0059122	35	37
.0043883	33	47	.0048989	29	37	.005417	13	15	.0059215	18	19
.0043922	26	37	.0049202	37	47	.0054348	20	23	.0059294	37	39
.004398	19	27	.0049244	26	33	.0054434	27	31	.0059375	19	20
.0044119	12	17	.0049345	15	19	.0054486	34	39	.0059455	39	41
.004421	29	41	.004942	34	43	.0054522	41	47	.0059524	20	21
.0044354	22	31	.0049569	23	29	.005469	14	16	.0059598	41	43
.0044643	15	21	.0049677	31	39	.0054848	43	49	.0059782	22	23
.0044643	35	49	.0049745	39	49	.0054878	36	41	.0059841	45	47
.0044871	28	39	.005	16	20	.0054924	29	33	.0059951	47	49
.004506	31	43	.005	12	15	.0055148	15	17	.0060188	26	27
.004514	13	18	.0050308	33	41	.0055238	38	43	.0060346	28	29
.0045213	34	47	.0050402	25	31	.0055555	24	27	.006048	30	31
.0045259	21	29	.0050532	38	47	.0055555	16	18	.0060607	32	33
.0045452	24	33	.0050596	17	21	.0055746	33	37	.0060812	36	37
.004561	27	37	.0050676	30	37	.0055852	42	47	.0060898	38	39
.0045732	30	41	.0050785	13	16	.0055925	17	19	.006098	40	41
.0045835	11	15	.0050876	35	43	.0056035	26	29	.0061052	42	43
.004592	36	49	.0050928	22	27	.0056088	35	39	.0061171	46	47
.0046055	14	19	.0051022	40	49	.0056123	44	49	.0061224	48	49
.0046194	17	23	.0051136	27	33	.005625	18	20	.00625		1
.0046296	20	27	.0051281	32	39	.0056403	37	41			
.0046371	23	31	.0051474	14	17	.005645	28	31			
.0046473	29	39	.0051627	19	23	.0056546	19	21			
.0046512	32	43	.0051721	24	29	.005669	39	43			
.0046543	35	47	.005183	34	41	.0056816	30	33			
.0046875	15	20	.0051861	39	47	.0057065	21	23			
.0046875	12	16	.0052083	15	18	.005718	43	47			
.0047195	37	49	.0052296	41	49	.00574	45	49			

Lubricants for Cutting Tools

Material	Turning	Chucking	Drilling Milling	Reaming	Tapping
Tool Steel	Dry or Oil	Oil or Soda Water	Oil	Lard Oil	Oil
Soft Steel	Dry or Soda Water	Soda Water	Oil or Soda Water	Lard Oil	Oil
Wrought Iron	Dry or Soda Water	Soda Water	Oil or Soda Water	Lard Oil	Oil
Cast Iron	Dry	Dry	Dry	Dry	Oil
Brass	Dry	Dry	Dry	Dry	Oil
Copper	Dry	Oil	Oil	Mixture	Oil
Babbitt	Dry	Dry	Dry	Dry	Oil
Glass			Turpentine or	Kerosene	

Mixture is 1/3 Crude Petroleum, 2/3 Lard Oil. When two lubricants are mentioned the first is preferable.

TABLE OF DIVISIONS OBTAINED WITH STANDARD INDEX PLATE

INDEX TABLE FOR CINCINNATI MILLING MACHINE

This plate is reversible; drilled on both sides with holes as follows: First side—24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43. Second side—46, 47, 49, 51, 53, 54, 57, 58, 59, 62, 66.

It indexes all numbers up to and including 60, all even numbers and those divisible by 5 up to 120, and many beyond those shown in the table.

No. of Divisions	Circle	Turns	Holes	No. of Divisions	Circle	Turns	Holes	No. of Divisions	Circle	Holes	No. of Divisions	Circle	Holes	No. of Divisions	Circle	Holes	No. of Divisions	Circle	Holes	No. of Divisions	Circle	Holes	No. of Divisions	Circle	Holes
2	any	20	....	**23**	46	1	34	**44**	66	60	**68**	34	20	**104**	39	15	**150**	30	8	**205**	41	8	**280**	28	4
3	24	13	8	**24**	24	1	16	**45**	54	48	**70**	28	16	**105**	42	16	**152**	38	10	**210**	42	8	**290**	58	8
4	any	10	....	**25**	25	1	15	**46**	46	40	**72**	54	30	**106**	53	20	**155**	62	16	**212**	53	10	**296**	37	5
5	any	8	....	**26**	39	1	21	**47**	47	40	**74**	37	20	**108**	54	20	**156**	39	10	**215**	43	8	**300**	30	4
6	24	6	16	**27**	54	1	6	**48**	24	20	**75**	30	16	**110**	66	24	**160**	28	7	**216**	54	10	**304**	38	5
7	28	5	20	**28**	42	1	18	**49**	49	40	**76**	38	20	**112**	28	10	**164**	41	10	**220**	66	12	**310**	62	8
8	any	5	....	**29**	58	1	22	**50**	25	20	**78**	39	20	**114**	57	20	**165**	56	16	**224**	28	5	**312**	39	5
9	54	4	24	**30**	24	1	8	**51**	51	40	**80**	34	17	**115**	46	16	**168**	42	10	**228**	57	10	**320**	24	3
10	any	4	....	**31**	62	1	18	**52**	39	30	**82**	41	20	**116**	58	20	**170**	34	8	**230**	46	8	**328**	41	5
11	66	3	42	**32**	28	1	7	**53**	53	40	**84**	42	20	**118**	59	20	**172**	43	10	**232**	58	10	**330**	66	8
12	24	3	8	**33**	66	1	14	**54**	54	40	**85**	34	16	**120**	66	22	**176**	66	15	**235**	47	8	**336**	42	5
13	39	3	3	**34**	34	1	6	**55**	66	48	**86**	43	20	**124**	62	20	**180**	54	12	**236**	59	10	**340**	34	4
14	49	2	42	**35**	28	1	4	**56**	28	20	**88**	66	30	**125**	25	8	**184**	46	10	**240**	66	11	**344**	43	5
15	24	2	16	**36**	54	1	6	**57**	57	40	**90**	54	24	**130**	39	12	**185**	37	8	**245**	49	8	**360**	54	6
16	24	2	12	**37**	37	1	3	**58**	58	40	**92**	46	20	**132**	66	20	**188**	47	10	**248**	62	10	**368**	46	5
17	34	2	12	**38**	38	1	2	**59**	59	40	**94**	47	20	**135**	54	16	**190**	38	8	**250**	25	4	**370**	37	4
18	54	2	12	**39**	39	1	1	**60**	42	28	**95**	38	16	**136**	34	10	**192**	24	5	**255**	51	8	**376**	47	5
19	38	2	4	**40**	any	1	....	**62**	62	40	**96**	24	10	**140**	28	8	**195**	39	8	**260**	39	6	**380**	38	4
20	any	2	....	**41**	41	....	40	**64**	24	15	**98**	49	20	**144**	54	15	**196**	49	10	**264**	66	10	**390**	39	4
21	42	1	38	**42**	42	....	40	**65**	39	24	**100**	25	10	**145**	58	16	**200**	30	6	**270**	54	8	**392**	49	5
22	66	1	54	**43**	43	....	40	**66**	66	40	**102**	51	20	**148**	37	10	**204**	51	10	**272**	34	5	**400**	30	3

A Plate of Free Hand Lettering

ABCDEFGHIJKLMNOP

QRSTUV WX

1234567890 YZ

abcdefghijklmnop

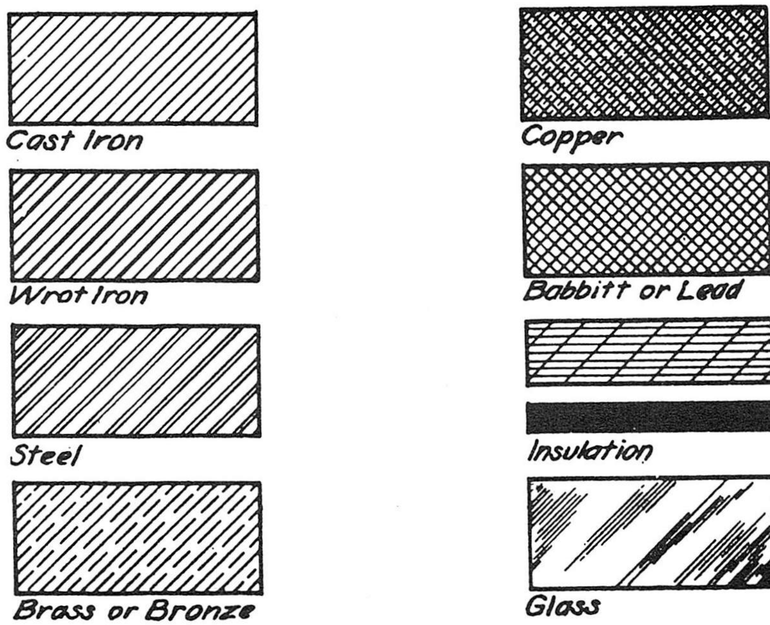
qrstuvwxyz

THE ART OF LETTERING MAY

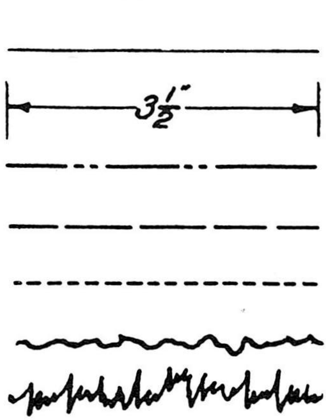
BE ACQUIRED BY PRACTICE.

Utility is the first requisite of a working drawing. Care and judgement must be exercised at all times.

— MATERIALS IN SECTION —



—ALPHABET OF LINES—



Visible outline

Invisible outline

Center line

Extension line

Cross-hatching line

Dimension line

Cutting plane

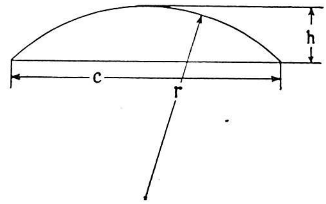
Alternate position

Line of motion

Broken metal

Broken wood

Area and Volume of Spherical Segments



Where r = radius
c = length of cord
h = height

Area of Curved Surface $= 2\,\pi\, rh = \frac{\pi}{4}(4h^2 + c^2)$

Volume of Segment $= \frac{\pi}{3} h^2 (3r - h) = \frac{\pi}{24} h (3c^2 + 4h^2)$

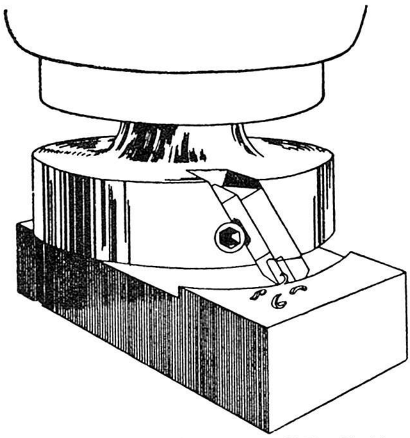
Capacity of Cylindrical Tanks and Cisterns

1 gallon = 231 cubic inches = 0.13368 cubic foot
1 cubic foot = 7.4805 gallons
Capacities given in U.S. gallons for 1 foot in depth

Diameter, ft.	Diameter, in.	Area, square feet	Gallons, 1 foot depth	Diameter, ft.	Diameter, in.	Area, square feet	Gallons, 1 foot depth	Diameter, ft.	Diameter, in.	Area, square feet	Gallons, 1 foot depth
1	0	.785	5.87	5	8	25.22	188.66	19	0	283.53	2120.9
1	1	.922	6.89	5	9	25.97	194.25	19	3	291.04	2177.1
1	2	1.069	8.00	5	10	26.73	199.92	19	6	298.65	2234.0
1	3	1.227	9.18	5	11	27.49	205.67	19	9	306.35	2291.7
1	4	1.396	10.44	6	0	28.27	211.51	20	0	314.16	2350.1
1	5	1.576	11.79	6	3	30.68	229.50	20	3	322.06	2409.2
1	6	1.767	13.22	6	6	33.18	248.23	20	6	330.06	2469.1
1	7	1.969	14.73	6	9	35.78	267.69	20	9	338.16	2529.6
1	8	2.182	16.32	7	0	38.48	287.88	21	0	346.36	2591.0
1	9	2.405	17.99	7	3	41.28	308.81	21	3	354.66	2653.0
1	10	2.640	19.75	7	6	44.18	330.48	21	6	363.05	2715.8
1	11	2.885	21.58	7	9	47.17	352.88	21	9	371.54	2779.3
2	0	3.142	23.50	8	0	50.27	376.01	22	0	380.13	2843.6
2	1	3.409	25.50	8	3	53.46	399.88	22	3	388.82	2908.6
2	2	3.687	27.58	8	6	56.75	424.48	22	6	397.61	2974.3
2	3	3.976	29.74	8	9	60.13	449.82	22	9	406.49	3040.8
2	4	4.276	31.99	9	0	63.62	475.89	23	0	415.48	3108.0
2	5	4.587	34.31	9	3	67.20	502.70	23	3	424.56	3175.9
2	6	4.909	36.72	9	6	70.88	530.24	23	6	433.74	3244.6
2	7	5.241	39.21	9	9	74.66	558.51	23	9	443.01	3314.0
2	8	5.585	41.78	10	0	78.54	587.52	24	0	452.39	3384.1
2	9	5.940	44.43	10	3	82.52	617.26	24	3	461.86	3455.0
2	10	6.305	47.16	10	6	86.59	647.74	24	6	471.44	3526.6
2	11	6.681	49.98	10	9	90.76	678.95	24	9	481.11	3598.9
3	0	7.069	52.88	11	0	95.03	710.90	25	0	490.87	3672.0
3	1	7.467	55.86	11	3	99.40	743.58	25	3	500.74	3745.8
3	2	7.876	58.92	11	6	103.87	776.99	25	6	510.71	3820.3
3	3	8.296	62.06	11	9	108.43	811.14	25	9	520.77	3895.6
3	4	8.727	65.28	12	0	113.10	846.03	26	0	530.93	3971.6
3	5	9.168	68.58	12	3	117.86	881.65	26	3	541.19	4048.4
3	6	9.621	71.97	12	6	122.72	918.00	26	6	551.55	4125.9
3	7	10.085	75.44	12	9	127.68	955.09	26	9	562.00	4204.1
3	8	10.559	78.99	13	0	132.73	992.91	27	0	572.56	4283.0
3	9	11.045	82.62	13	3	137.89	1031.5	27	3	583.21	4362.7
3	10	11.541	86.33	13	6	143.14	1070.8	27	6	593.96	4443.1
3	11	12.048	90.13	13	9	148.49	1110.8	27	9	604.81	4524.3
4	0	12.566	94.00	14	0	153.94	1151.5	28	0	615.75	4606.2
4	1	13.095	97.96	14	3	159.48	1193.0	28	3	626.80	4688.8
4	2	13.635	102.00	14	6	165.13	1235.3	28	6	637.94	4772.1
4	3	14.186	106.12	14	9	170.87	1278.2	28	9	649.18	4856.2
4	4	14.748	110.32	15	0	176.71	1321.9	29	0	660.52	4941.0
4	5	15.321	114.61	15	3	182.65	1366.4	29	3	671.96	5026.6
4	6	15.90	118.97	15	6	188.69	1411.5	29	6	683.49	5112.9
4	7	16.50	123.42	15	9	194.83	1457.4	29	9	695.13	5199.9
4	8	17.10	127.95	16	0	201.06	1504.1	30	0	706.86	5287.7
4	9	17.72	132.56	16	3	207.39	1551.4	30	3	718.69	5376.2
4	10	18.35	137.25	16	6	213.82	1599.5	30	6	730.62	5465.4
4	11	18.99	142.02	16	9	220.35	1648.4	30	9	742.64	5555.4
5	0	19.63	146.88	17	0	226.98	1697.9	31	0	754.77	5646.1
5	1	20.29	151.82	17	3	233.71	1748.2	31	3	766.99	5737.5
5	2	20.97	156.83	17	6	240.53	1799.3	31	6	779.31	5829.7
5	3	21.65	161.93	17	9	247.45	1851.1	31	9	791.73	5922.6
5	4	22.34	167.12	18	0	254.47	1903.6	32	0	804.25	6016.2
5	5	23.04	172.38	18	3	261.59	1956.8	32	3	816.86	6110.6
5	6	23.76	177.72	18	6	268.80	2010.8	32	6	829.58	6205.7
5	7	24.48	183.15	18	9	276.12	2065.5	32	9	842.39	6301.5

Rectangular Tanks

To find the capacity of rectangular tanks multiply the length by the width by the depth (all in inches) and divide the result by 231. The answer is the capacity in gallons.



Single-Bladed "Kennamill" Cutter

At a time when manufacturers of standard milling cutters are unable to keep up with the demand, McKenna Metals Co., 381 Lloyd Ave., Latrobe, Pa., announces a method by which simple facing cutter heads may be made in almost any shop. Due to its high speed of cutting, this single-bladed "Kennamill," employing Kennametal tools, will often work more efficiently than a standard cutter requiring many high speed steel blades.

Designed with a large negative spiral angle of 35° to 55° and positive hook of 15° to 25°, this cutter mills steel efficiently only because Kennametal does not "gall" or permit the adherence of steel chips to the hard, strong, non-galling tool tip which "skids" the steel chip off smoothly at these angles.

For roughing, with cuts up to ⅜" deep, a 35° negative helical angle and 15° positive hook on a 12" diameter cutter head has been found to work efficiently. For light finishing cuts a negative helic of 55° with 20° positive hook angle is most efficient. The hook angle should be less on a smaller diameter head.

Kennametal cutters should be run to give 300 to 600 ft. per min. peripheral speed, with a table feed of .008" per revolution, depending on the material being machined. A 6" dia. head gives about 3" per min. table feed at 380 r.p.m. (600 ft./min. cutting speed.) Clearances should be kept to a minimum and only a slight radius used. No coolant should be used as it is impossible to keep the cutting point flooded at the speeds employed.

The Kennametal-tipped blades can be removed from the cutter heads and reground quickly, an important advantage over standard cutters, which require removal of the entire head from the machine, with consequent loss of time.

The manufacturer will be pleased to furnish additional information upon request.

Cam Cutting

Although, in most factories, the operations discussed in this chapter are looked upon as toolroom jobs, there are numerous concerns in which cam and gear cutting are strictly manufacturing propositions. Many screw machine shops lay out and make their own cams — using a milling machine for the purpose — in such quantities that a machine may be employed almost exclusively for cam cutting. Other shops have to cut all sorts of gears — spur, spiral, bevel, etc., — but in such small lots that the installation of sufficient gear cutting machinery to fill their requirements in variety would call for a prohibitive outlay of capital, and would burden them with a number of machines that could be kept busy only a fraction of the time. In this type of

(Continued on top of next page.)

plant it is not unusual to see one or more milling machines engaged primarily upon gear cutting.

Graduating is more likely to be confined to an occasional toolroom or experimental job, but, since it involves the use of the Universal Index Centers in conjunction with table movements, as do so many gear and cam cutting operations, we have included it in this chapter.

Face, peripheral and cylindrical cams of all ordinary sizes can be cut upon a milling machine, and a far more satisfactory job can be obtained than is possible by drilling around the outline on a cam blank, breaking it off and then milling or filing to a line.

When it is required to cut several cams of the same outline at frequent intervals, it is an advantage to add the Cam Cutting Attachment, illustrated and described in Chapter II, to the equipment of the machine. The formers that are required to produce the different cams can be preserved, and it is then only a matter of a few minutes' time to set up the machine to cut any number of cams for which a former is at hand.

Another method that is often followed, in cutting peripheral cams, especially those for use on automatic screw machines, is that of using the universal spiral index head and a vertical milling attachment.

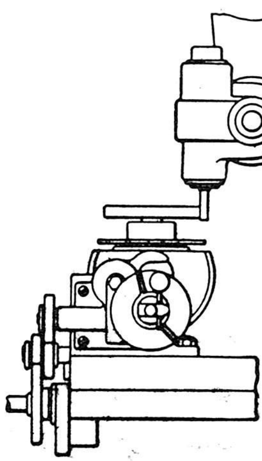


Fig. 1

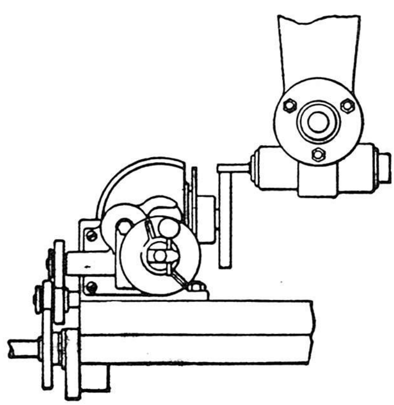


Fig. 2

Cam Cutting Attachment. The headstock is geared to the table feed screw, the same as in cutting ordinary spirals, and the cam blank is fastened to the end of the index spindle. An end mill is used in the vertical milling attachment, which is set in each case to mill the periphery of the cam at right-angles to its sides, or, in

Continued on next page

other words, the axes of the headstock spindle and attachment spindle must always be parallel to mill cams according to this method. The cutting is done by the teeth on the periphery of the end mill. The principle of this method is as follows: Suppose the headstock is elevated to 90°, or at exact right angles to the surface of the table (see Fig. 1), and is geared for any given lead. It is then apparent that, as the table advances and the blank is turned, the distance between the axes of the index spindle and attachment spindle becomes less. In other words, the cut becomes deeper and the radius of the cam is shortened, producing a spiral lobe, the lead of which is the same as that for which the machine is geared.

Now, suppose the same gearing is retained and the headstock is set at zero, or parallel to the surface of the table (see Fig. 2). It is apparent, also, that the axes of the index spindle and attachment spindle are parallel to one another. Therefore, as the table advances, and the blank is turned, the distance between the axes of the index spindle and attachment spindle remains the same. As a result, the periphery of the blank, if milled, is concentric or the lead is 0.

If, then, the headstock is elevated to any angle between zero and 90° (see Fig. 3), the amount of lead given to the cam will be between that for which the machine is geared and 0. Hence it is clear that cams with a very large range of different leads can be obtained with one set of change gears, and the problem of milling the lobes of a cam is reduced to a question of finding the angle at which to set the head to obtain any given lead.

In order to illustrate the method of obtaining the correct angle, drawings of two cams to be milled, and data connected with same, are given in Figs. 4 and 5.

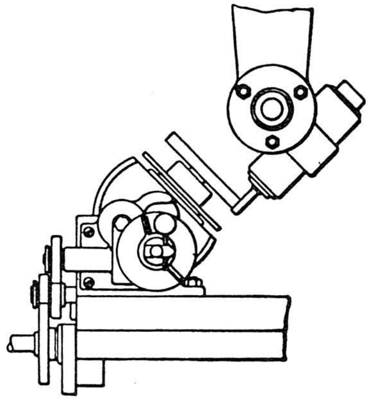


Fig. 3

It is first necessary to know the lead of the lobes of a cam, that is, the amount of rise of each lobe if continued the full circumference of the cam. This can be obtained from the drawings as follows: For cams where the face is divided into hundredths, as those shown: multiply 100 by the rise of the lobe in inches and divide by the number of hundredths of circumference occupied by the lobe. For cams that are figured in degrees of circumference: multiply 360 by the rise of the lobe in inches and Continued on next page

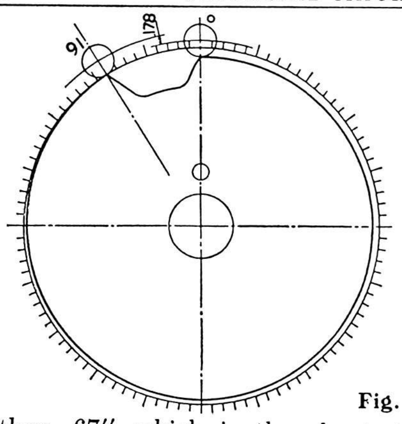


Fig. 4

divide by the number of degrees of circumference occupied by the lobe. Taking Fig. 4 for example, we have a cam of one lobe which extends through 91 hundredths of the circumference, and has a rise .178″. Then $\frac{100 \times .178''}{91} = .1956$ lead of lobe, or .196″, which is near enough for all practical purposes.

As a .196″ lead is much less than .67″, which is the shortest lead regularly obtainable on the milling machine.

Divide the given lead of the cam lobe by a lead obtainable on the machine, and the result is the sine of the angle at which to set the head.

Continuing the calculation for the lobe of the cam in Fig. 4, we therefore have: $\frac{.196''}{.67''} = .29253.$

Hence, .29253 is the sine of the correct angle. Turning to a table of natural sines and cosines, we find that .29253 is very near .29265, which is the sine of an angle of 17° and 1′. As the headstock is not graduated closer than quarter degrees, it will be satisfactory to elevate the head just a hair over 17°; then, with the gearing for a lead of .67″, a cam with a lead of .196″ will be obtained.

The minute errors between the actual lead .1956″ and .196″, and in the sines and angles of this calculation can be safely ignored, as it is not possible in practice to work very much closer than we have outlined.

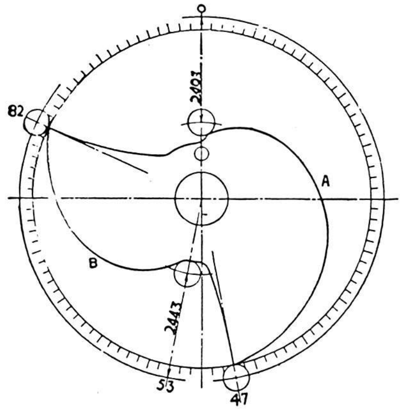


Fig. 5

The portion of the periphery of the cam from 91 hundredths to zero represents a clearance of the cutting tool prior to the beginning of the throw. It is usually milled to a line, or drilled, broken out, and filed.

In Fig. 5, we have a cam with two lobes, one, A, having a rise of 2.493″ in 47 hundredths, and the other, B, having a rise of 2.443″ in 29 hundredths. On

cams such as this, where it is necessary to remove considerable stock, it is usually the practice to first outline the approximate shape of the lobes on the blank and drill and break off the surplus stock.

Following the same method of figuring to find the lead of the lobes on this cam, we have: $\frac{100 \times 2.493''}{47} = 5.304''$ lead for lobe A, and $\frac{100 \times 2.443''}{29} = 8.424''$ lead for lobe B.

Where there are two or more lobes on a cam, the machine is geared for a lead slightly longer than the longest one required, which in this case is 8.424″, then the other lobes are milled without changing the gears. Referring to the Table of Leads, we find a lead of 8.437″, which is slightly larger than 8.424″. This gearing is, therefore, accepted, and it is required to find the sine of the angle at which to set the head for lobe B.

$\frac{8.424}{8.437} = .99846$ sine of angle at which to set head. Looking at a table of sines and cosines, .99846 is found to be the sine of an angle of 86° and 49′. The head is, therefore, set at a trifle over 86 3/4°.

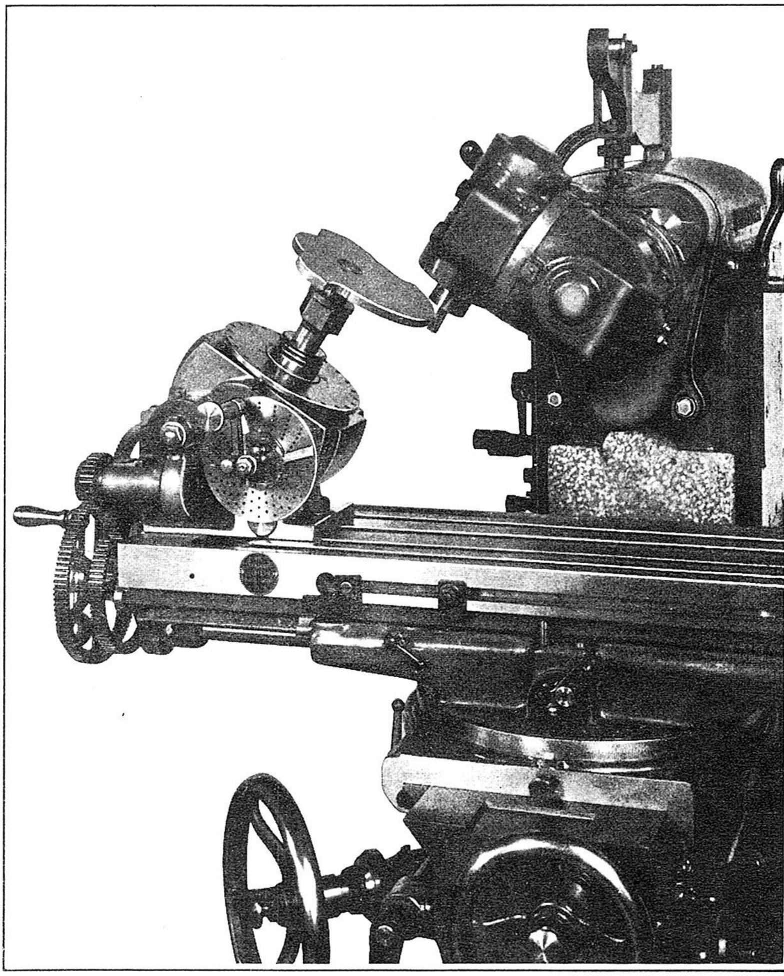
When lobe B has been milled, the head is set for lobe A.

$\frac{5.304}{8.437} = .62865$ sine of an angle at which to set head. Referring again to a table of sines and cosines, we find that .62865 is very near to .62864, which is the sine of an angle of 38° and 57′. The head is, therefore, set slightly under 39° for this lobe.

The other portions of the periphery of this cam are formed up either by filing to a line before the blank is put on the milling machine or by milling to the line after the lobes have been formed.

Whenever possible, the job should be set up so that the end mill will cut on the lower side of the blank, as this brings the mill and table nearer together and makes the job more rigid. It also prevents chips from accumulating, and enables the operator to better see any lines that may be laid out on the face of the cam.

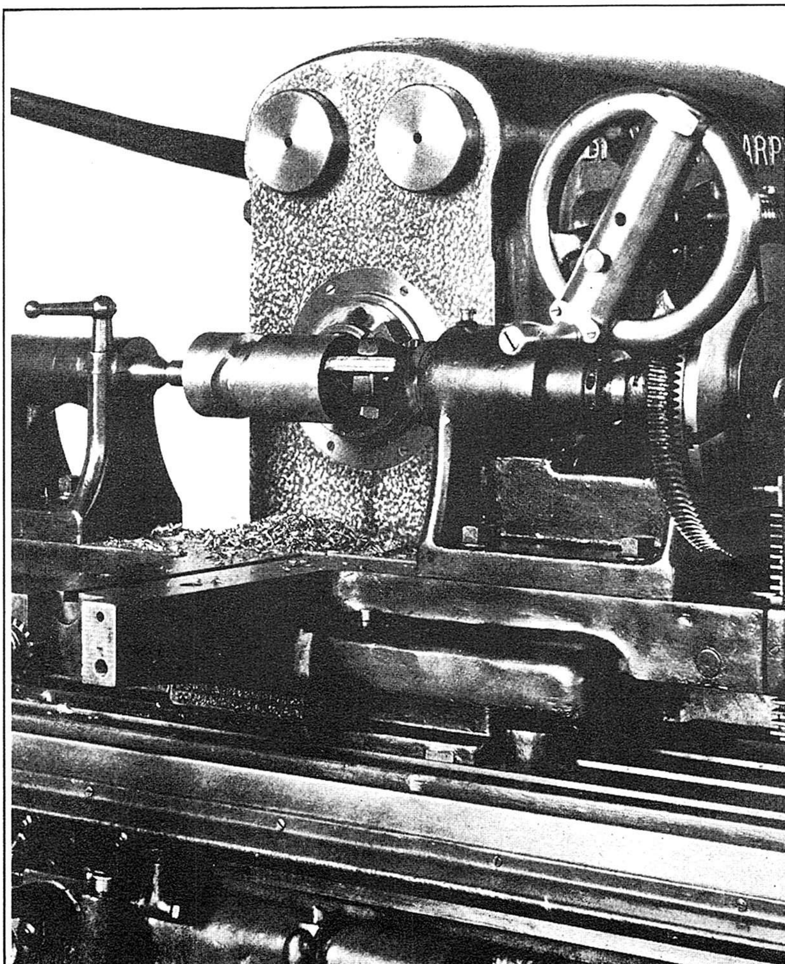
When the lead of the machine is over 2″ the automatic feed can be used, but when the lead is less than 2″ the job should be fed by hand, with the index crank, unless a short lead attachment is used.



Milling a Cam, Using Universal Spiral Index Head and Vertical Milling Attachment

The cam blank is mounted on an expansion arbor inserted in the taper hole of the headstock spindle.

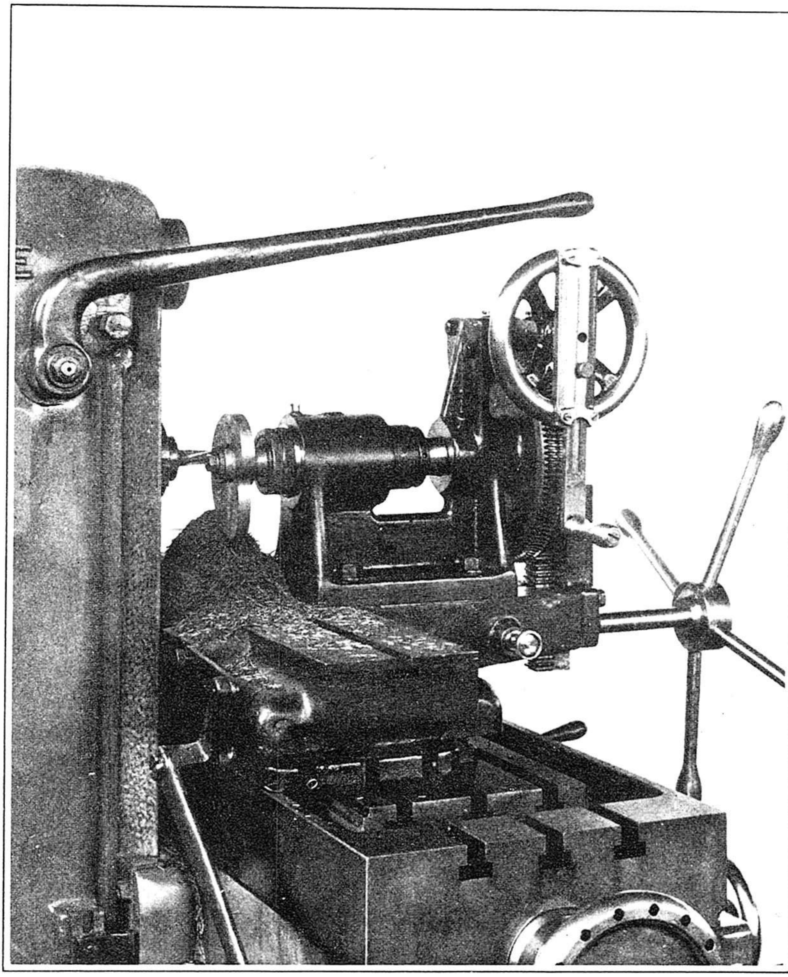
Suitable change gears are selected to give the approximate lead and the headstock is elevated to obtain the exact lead; the vertical attachment is then set to bring the end mill parallel with the axis of the cam. Where such short leads as this are being milled, there is great stress brought upon the headstock gearing in attempting to use the automatic feed, unless a short lead attachment, such as is used here, is available.



Cutting a Cylindrical Cam, Using Cam Milling Attachment

For cutting a cylindrical cam, the attachment head and footstock are bolted to the bed parallel to the table and the cam blank is supported on an arbor mounted on the attachment centers. The attachment centers are placed at the same height as the axis of the spindle. A spiral end mill is used for this operation and the necessary movement to feed the work is obtained from the attachment, the table remaining clamped in one position.

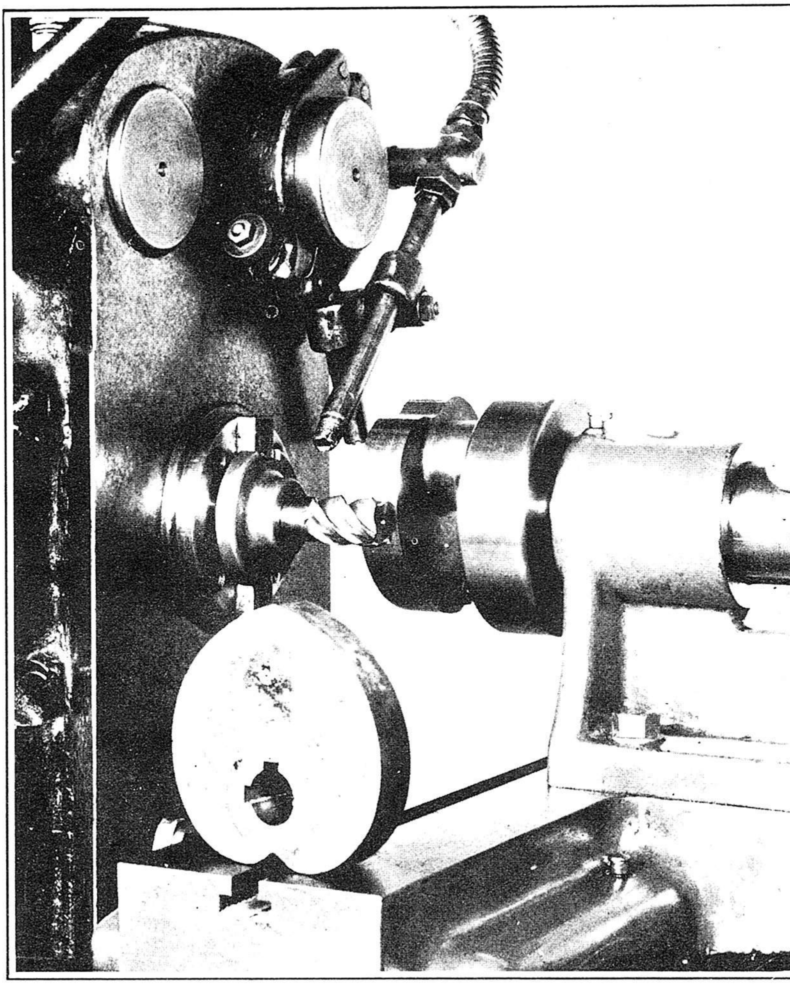
The former, itself a cam, is usually made with the aid of the universal spiral index head, in the manner previously described.



Cutting a Peripheral Cam, Using the Cam Milling Attachment

In this operation the head of the attachment is bolted to the bed at right angles to the table and the cam blank is fastened to the attachment spindle by means of a bolt. A face cam would be milled in the same manner. The necessary rotative movement is obtained by hand feed, and the longitudinal movement to give the proper lead and shape to the cam is produced by the cam former and the mechanism of the attachment, as described.

A spiral end mill is used. The machine table remains clamped in one position.



Milling Heart Shaped Cam

The cam shown in place on the cam milling attachment in this photograph required a method of machining that is a little out of the ordinary, because of the abrupt rise and drop of the lobes.

To overcome the stresses caused by these steep lobes, a former was made in the same shape as the required cam, but with its center of rotation much closer to its actual center than in the case of the work itself. The work was then mounted upon a special holder with a stud to fit the hole in the work, offset the proper distance. By this means, such heart shaped cams can be milled more easily and accurately.

Cam Milling Attachment

The Cam Milling Attachment, shown in Fig. 1, is used for cutting either Face, Peripheral or Cylindrical Cams from a flat former. The former is made from a disk about ½ inch thick, on which the required outline is laid out. The disk is machined or filed to the required shape.

The table of the machine remains clamped in one position during cutting, and the necessary rotative and longitudinal movements are contained in the mechanism itself. The rotative movement is obtained by a worm driving a wormwheel fixed to the spindle of the attachment. The former is secured to the face of the wormwheel, and

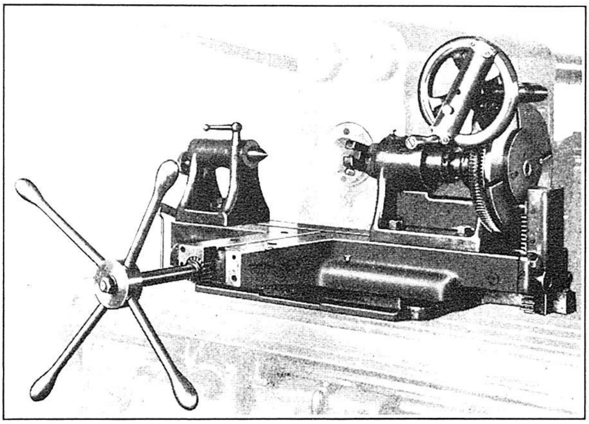


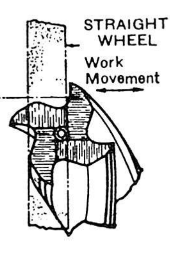
Fig. 1. Cam Milling Attachment

as the wheel revolves, the former depresses a sliding rack that in turn drives a pinion geared to another rack in the sliding bed of the attachment, thus giving the necessary longitudinal movement. In the illustration, the former is shown in position on the face of the wormwheel.

The attachment is sometimes driven automatically by means of a round belt leading from a small jackshaft to a three-step cone pulley fastened on the end of the worm shaft. The pulley is clutched to the worm so that either hand or automatic feed may be used by the simple movement of a lever.

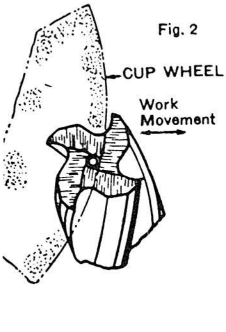
In sharpening Brown & Sharpe Spiral End Mills and Two Lipped Spiral End Mills the double angle lands with which these mills are furnished should be preserved. These double angle lands permit the correct cutting clearance to be maintained with a strong tooth shape.

Fig. 1



In sharpening End Mills having end teeth as shown in the illustrations, either a straight wheel can be used as shown in Fig. 1 or a cup wheel as shown in Fig. 2. Wheels should be set to give approximately 4° cutting clearance and sufficient concavity to make the points of the teeth higher than any other part. Should repeated sharpenings eliminate the center hole, the efficiency of the end mill is not impaired.

Fig. 2



BELTING SECTION

The driving power of a single belt is usually taken as one horse-power for every inch of width at a speed of 600 to 700 feet per minute, from 400 to 500 feet per minute for a double belt.

To find the length of belt wanted. Add the diameter of both pulleys together, divide by 2, and multiply quotient by 3¼; add this product to twice the distance in inches between the center of shafts, and the final sum will be the length required. Example. Diameter of large pulley 24 in. + 12 diameter of small pulley = 36 ÷ 2 = 18 × 3¼ = 58½ + 216 twice distance between shafts = 274½ inches, length required.

To find width of belt required for a given horse-power. Multiply the horse-power by the constant 2,750, then multiply the diameter by driven pulley by the number of revolutions and divide the first product by the latter, the quotient will be the width of belt required. Example. Horse-power 28 × constant 2,750 = 77,000; diameter of pulley 36 in. × revolution 200 = 7,200; 77,000 ÷ 7,200 = 10 inches, width required.

To find the horse-power which a belt will transmit. Multiply the width of belt by diameter of driven pulley in inches, multiply this product by revolutions per minute, then divide final product by constant 2,750, the quotient will be the horse-power. Example. Belt 10 in. × 36 diameter of pulley = 360 × 200 revolutions = 72,000 ÷ 2,750 constant = 26.5 horse-power required.

The horse-power and width of belt given, find the diameter of driven pulley required. Multiply the horse-power by constant 2,750, now multiply revolutions of pulley by width of belt, then divide the first product by the latter, the quotient will be the diameter wanted. Example. Horse-power 28 × 2,750 = 77,000; revolutions 200 × 10 = 2,000; 77,000 ÷ 2,000 = 38.5, diameter wanted.

To find the size of driving pulley, multiply the diameter driven by revolutions it should make, and divide the product by revolutions of driver. Example. Diameter of driven, 12 inches; revolutions, 240; revolutions of driver, 160 then 12 × 240 = 2,880 ÷ 160 = 18, diameter of driver wanted.

To find the size of driven pulley, multiply diameter of driver by its revolutions, and divide the product by revolutions of driven. Example. Diameter of driver, 18; revolutions, 160; revolutions of driven, 240: then 18 × 160 = 2,880 ÷ 240 = 12, revolutions of driven wanted.

To find the number of revolutions of driven, multiply diameter of driver by its revolutions, and divide product by diameter of driven. Example. Diameter of driver, 18; revolutions, 160; diameter of driven, 12 inches; then 18 × 160 = 2,880 ÷ 12 = 240, revolutions of driven wanted.

To find the horse-power of a driving pulley, multiply the circumference of pulley by the revolutions, and this product by width of belt, and divide final product by 600. Example. Circumference of pulley, 56.55; revolutions, 160; width of belt, 6 inches; then 56.55 × 160 = 9,048 × 6 = 54,288 ÷ 600 = 9.04, horse-power of pulley wanted.

To find the length of belt when closely rolled, add the diameter of the roll in inches to the diameter of the eye, multiply this by the number of turns. The result multiplied by the decimal, 1309, will give the length of roll in feet.

BELT CEMENT

For leather belts, take of common glue and American isinglass equal parts; place them in a glue pot and add water sufficient to cover the whole. Let it soak 10 hours, then bring the whole to a boiling heat, and add pure tannin until the whole appears like the white of an egg. Apply warm. Buff the grain of the leather where it is to be cemented, rub the joint surfaces solidly together, let it dry for a few hours, and the belt will be ready for use. For rubber belts take 16 parts of gutta percha, 4 parts india rubber, 2 parts common calker's pitch, 1 part linseed oil; melt together and use hot. This cement can also be used for leather.

Keep your belt speeds up.

Within reasonable limits and ignoring the effect of centrifugal force, doubling belt speed doubles the horsepower a given belt will transmit, or cuts in half the stress in the belt for the same horsepower. So keep belt speeds up — to keep belt costs down.

Speeds for engine or lineshaft drive belts.

To figure a belt drive from an engine or lineshaft or for any purpose other than an electric motor drive, again make the diameter of your driving pulley to give as high belt speed as is possible — from 3,500 to 4,500 F.P.M. This is the safe way to get a drive that will perform well — and *be cheaper*, because of the narrower belt and pulleys that can be used.

What belt thickness to use.

Having determined suitable motor or driving pulley for your job and knowing the belt speed, your next step is to determine *thickness of belt* to use. The diameter of the small pulley in the drive determines the belt thickness. This is important. The smaller the diameter of the pulley around which the belt bends, the quicker the belt will wear out. So belt thickness depends on the diameter of the small pulley.

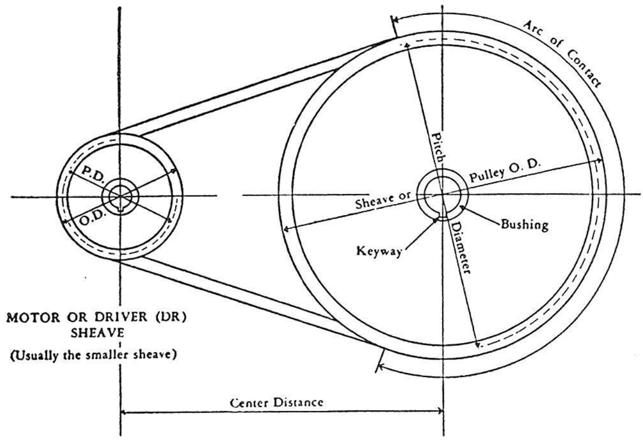
Referring to table below, if the small pulley is 4″ diameter then a *medium single* belt is recommended. If the small pulley is 8″ diameter a *medium double* belt is recommended. But if, for the 8″ diameter pulley, the belt finally figures more than 8 inches in width, then, to better conform to the wider and higher pulley crown, a *light double* is recommended.

ALWAYS USE BELT THICKNESS THAT IS CORRECT FOR PULLEY DIAMETER

	SINGLE PLY		DOUBLE PLY			TRIPLE PLY	
	Med.	Heavy	Light	Med.	Heavy	Med.	Heavy
	These are the minimum recommended pulley diameters for the above thickness belts						
Belts Under 8″ Wide	3″	5″	6″	8″	12″		
Belts 8″ and Wider			8″	10″	14″	24″	30″

BELTING—V-Shaped

V-BELT DRIVES



ARC OF CONTACT: Amount of wrap or measure of belt contact with pulley measured in degrees. See sketch.

CENTER DISTANCE: Distance between axis of pulley or sheave shafts, see sketch. The best center distance is one that approximately equals the diameter of the large sheave. Do not use a center distance greater than the sum of the diameters of both sheaves unless necessary.

COMBINATION STOCK DRIVE: A drive incorporating a Light Duty sheave and Standard sheave in combination with a standard length belt.

FIXED CENTER DRIVE: A drive where no take-up for belt stretch is provided. Avoid such a design if possible.

R. P. M.: Number of Revolutions Per Minute made by sheave. Driving sheave R. P. M.. can usually be obtain from name plate on prime movers, motors or engines. The most accurate information can best be obtained by use of a tachometer.

SHEAVE: Pulley with outside surface or periphery grooved to accommodate V-shaped belts.

(a) *Pitch Diameter (P. D.)*—Approximate location of neutral belt axis with reference to sheave groove where V-belt is in contact with sheave. *Belt speeds are figured on pitch diameters.*

(b) *Outside Diameter O.D.* —To get O.D. of sheave when P.D. is given see following table.

Belt Cross Section—	SHEAVES		BELTS		V-Flat Drive
	Recommended Range of Small Sheave Diameters	To Obtain O.D. of Sheaves Add to Pitch Diameter	To Obtain Pitch Length	To Obtain Outside Length	Add to O.D. of Flat Pulley to Obtain P.D.
			Add to Inside Circum.		
FHP. 0000—13/32″ x 7/32″	1.5″— 2.5″	.14″	.69″	1.38″	7/32″
FHP. 1000—33/64″ x 19/64″	2.0″— 3.0″	.19″	.93″	1.86″	19/64″
FHP. 2000—21/32″ x 23/64″	3.0″— 4.0″	.29″	1.13″	2.26″	23/64″
A—½″ x 11/32″	3.0″— 5.0″	⅜″	.98″	2.16″	11/32″
B—21/32″ x 7/16″	5.4″— 7.5″	½″	1.18″	2.75″	7/16″
C—⅞″ x 17/32″	9.0″—12.0″	¾″	1.57″	3.38″	17/32″
D—1¼″ x ¾″	13.0″—20.0″	⅞″	1.96″	4.71″	¾″
E—1½″ x 1″	21.6″—28.0″	1⅛″	2.75″	6.28″	1.0″

Continued on next page

(c) *Bushing*—Metallic lining used in hub of sheave. Inasmuch as the bushing can be bored to various diameters to fit shafting, most sheaves are manufactured to accommodate interchangeable bushings.

(d) *Hub*—Central part of sheave.

(e) *Bore*—The interior diameter of the hole in a hub or bushing.

(f) *Keyway or Keyseat*—Corresponding grooves in hub, bushing and shaft to accommodate key for locking bushing and hub in position to prevent rotation.

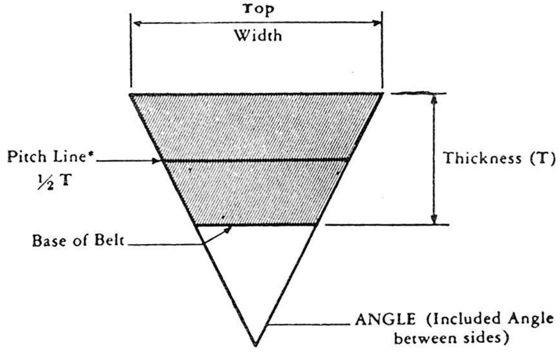
SPEED RATIO: Relation between speed of Driver (Dr.) Sheave and Driven (Dn.) Sheave. Can be obtained by dividing R.P.M. of smaller sheave by R.P.M. of larger sheave or by dividing pitch daimeter of larger sheave by pitch diameter of smaller sheave.

GLOSSARY OF TERMS—V-BELT DRIVES

STANDARD DRIVE: A drive incorporating standard size sheaves and standard length belts. Where stock sheaves are called for, the drive is termed a STANDARD STOCK DRIVE.

V-FLAT DRIVE: Name given drive where one pulley (usually the Driver) is V-grooved and the other pulley is a regular flat face pulley.

V-V DRIVE: This is a regular V-Belt drive and merely indicates that both pulleys are V-grooved.



*PITCH LINE OF BELT—Neutral axis of belt. Exact location depends upon several factors but for ordinary calculations can be considered as being half-way between top and base of belt.

PITCH LENGTH OF BELT—Length of belt measured along *Pitch Line.*

Horsepower	MOTOR SPEED—RPM						
	1750	1160	870	690	575	490	435
½	A*	A*	A	....	....	....	....
¾	A*	A	A	....	....	....	....
1	A	A	A	....	....	....	....
1½	A	A	A	....	....	....	....
2	A	A	A	....	....	....	....
3	A	A	B (or A)	....	....	....	....
5	B (or A)	B (or A)	B	....	....	....	....
7½	B	B	B	....	....	....	....
10	B	B	B or C	....	....		
15	B	B or C	C (or B)	....	....	....	....
20	B or C	C (or B)	C	D	D	....	....
25	C (or B)	C	C	D	D	....	....
30	C	C	C	D	D	....	....
40	C	C or D	C or D	D	D	....	....
50	C	C or D	C or D	D	D	E	E
60	C	C or D	D (or C)	D	D	E	E
75	C	D (or C)	D	D	D or E	E	E
100	C	D	D	D or E	E (or D)	E	E
125	....	D	D	D or E	E (or D)	E	E
150	....	D	D	E (or D)	E	E	E
200	....	D	D	E	E	E	E
250	....	D	D	E	E	E	E
300 and above	....	D	D	E	E	E	E

(Continued from preceding page)

CENTER DISTANCES: V-Belt Drives permit very short centers. Where no limitation of Minimum Center Distance is involved, a Center Distance equalling or slightly greater than the Large Pulley Diameter will usually give a very satisfactory and economical drive. It is simply necessary to have an Arc of Contact on the Small Pulley of approximately 120 degrees.

RECOMMENDED BELT CROSS-SECTIONS: The various Belt Cross-Sections should normally be used for the Horsepowers outlined in Table B on this page. Naturally, the smaller Cross-Section is used where the pulley diameters are limited.

MINIMUM PULLEY DIAMETERS: The Minimum Pulley Diameters shown in Table "A" will be found satisfactory for normal motor speeds. For slower speeds, these diameters should be increased if possible. Otherwise, due to the low belt velocity, more belts will be required. The Absolute Minimum Diameters may be used where the particular limitations of the drive make their use imperative. They should not be used, however, on V-Flat Drives or on applications subject to severe operating conditions, such as high starting torques, heavy peak loads, etc.

PITCH DIAMETERS: Pitch Diameters are determined by subtracting the amounts shown in Table "B" from the Outside Diameters. The amount to be subtracted depends on the Belt Cross-Section being used.

Cross-Section	TABLE "A" Minimum Pulley Diameters—Inches		TABLE "B" Outside and Pitch Diameters of Pulleys—Inches	
	Minimum Outside Diameters Recommended for Motor Pulleys	Absolute Minimum Outside Diameters or Motor Pulleys	Deduct from Outside Diameter of V-Pulley to Obtain Pitch Diameter	On V-Flat Drives, Add to Outside Diameter of Flat Pulley to Obtain Pitch Diameter
A	3	2½	*⅜	.25
B	5	4	*½	.35
C	8	7	¾	.45
D	11	10	⅞	.65
E	17	15	1⅛	.95

OVERLOADS OR PEAK LOADS: *Average Load Conditions* are those where the starting torque is equal to or less than full load torque and frequent peak loads are not encountered. For conditions more severe than average, *the number of belts should be increased.*

Where the Starting Torques or Peak Loads are greater than 100 per cent, but not over 150 per cent, of Full Load Values, use approximately 25 per cent more Belts.

Continued on next page

Where the Starting Torques or Peak Loads are greater than 150 per cent, but not over 200 per cent, of Full Load Values, use approximately 40 per cent more Belts.

Reversing Applications, such as cranes, hoists, etc., require approximately 25 per cent more Belts.

Textile Machines, such as Spinning Frames, usually require 40-50 per cent more Belts.

For Linestart Motor Applications, where the motor is started on full voltage, use approximately 20 per cent more Belts.

It is impossible to list all of the applications in the various industries that will require an increase in the number of belts, but, as a general rule, the foregoing corrections will apply.

The use of an increased number of belts under severe conditions, such as outlined above, will prevent slippage when starting or under peak loads, and will materially increase the life of the belts.

SURFACE SPEEDS IN FEET PER MINUTE
in Relation to RPM

Surface speed = diameter $\times \pi \times$ RPM $\div$ 12

Diam.	Revolutions per minute									
	10	11	12	13	14	15	16	17	18	19
½"	1.3090	1.4399	1.5708	1.7017	1.8326	1.9635	2.0944	2.2253	2.3562	2.4871
¾"	1.9635	2.1598	2.3562	2.5525	2.7490	2.9452	3.1416	3.3379	3.5343	3.7306
1"	2.6180	2.8798	3.1416	3.4034	3.6652	3.9270	4.1888	4.4506	4.7124	4.9742
1½"	3.9270	4.3197	4.7124	5.1051	5.4078	5.8905	6.2832	6.6759	7.0686	7.4613
2"	5.2360	5.7596	6.2832	6.8068	7.3304	7.8540	8.3776	8.9012	9.4248	9.9484
2½"	6.5450	7.1995	7.8540	8.5085	9.1630	9.8175	10.4720	11.1265	11.7810	12.4355
3"	7.8540	8.6394	9.4248	10.2102	10.9956	11.7810	12.5664	13.3518	14.1372	14.9226
3½"	9.1631	10.0794	10.9957	11.9121	12.8284	13.7447	14.6610	15.5773	16.4936	17.4099
4"	10.4720	11.5192	12.5664	13.6136	14.6608	15.7080	16.7552	17.8024	18.8496	19.8968
4½"	11.7810	12.9591	14.1372	15.3153	16.4934	17.6715	18.8496	20.0277	21.2057	22.3838
5"	13.0900	14.3990	15.7080	17.0170	18.3260	19.6350	20.9440	22.2529	23.5619	24.8709
6"	15.7080	17.2788	18.8496	20.4204	21.9911	23.5619	25.1327	26.7035	28.2743	29.8451
7½"	19.6350	21.5984	23.5619	25.5254	27.4889	29.4524	31.4159	33.3794	35.3429	37.3061
10"	26.1799	28.7993	31.4159	34.0339	36.6519	39.2699	41.8879	44.5059	47.1239	49.7419
12"	31.4159	34.5575	37.6991	40.8407	43.9823	47.1239	50.2655	53.4071	56.5487	59.6903

Diam.	Revolutions per minute								
	20	30	40	50	60	70	80	90	100
½"	2.6180	3.9270	5.2360	6.5450	7.8540	9.1630	10.4720	11.7810	13.0900
¾"	3.9270	5.8905	7.8540	9.8175	11.7810	13.7445	15.7080	17.6714	19.6350
1"	5.2360	7.8540	10.4720	13.0900	15.7080	18.3260	20.9440	23.5619	26.1799
1½"	7.8540	11.7810	15.7080	19.6350	23.5619	27.4889	31.4159	35.3429	39.2699
2"	10.4720	15.7080	20.9440	26.1799	31.4159	36.6519	41.8879	47.1239	52.3599
2½"	13.0900	19.6349	26.1799	32.7249	39.2699	45.8149	52.3598	58.9048	65.4498
3"	15.7080	23.5619	31.4159	39.2699	47.1239	54.9779	62.8319	70.6858	78.5398
3½"	18.3262	27.4894	36.6525	45.8156	54.9787	64.1418	73.3050	82.4681	91.6312
4"	20.9440	31.4159	41.8879	52.3599	62.8319	73.3038	83.7758	94.2478	104.7198
4½"	23.5619	35.3429	47.1239	58.9049	70.6858	82.4668	94.2478	106.0287	117.8097
5"	26.1799	39.2699	52.3599	65.4498	78.5398	91.6298	104.7198	117.8097	130.8997
6"	31.4159	47.1239	62.8319	78.5398	94.2478	109.9557	125.6637	141.3717	157.0796
7½"	39.2699	58.9049	78.5398	98.1748	117.8097	137.4447	157.0796	176.7146	196.3495
10"	52.3599	78.5398	104.7198	130.8997	157.0796	183.2596	209.4395	235.6195	261.7994
12"	62.8319	94.2478	125.6637	157.0796	188.4956	219.9115	251.3274	282.7433	314.1593

HORSEPOWER OF SINGLE LEATHER BELTING

Multiply diameter of pulley in inches by its number of revolutions per minute, and this product by width of the belt in inches; divide this product by 3,300 for single belting, or by 2,200 for double belting, and the quotient will be the amount of horsepower that can be safely transmitted.

Speed in Feet Per Min.	WIDTH OF BELTS IN INCHES										
	1	2	3	4	5	6	8	10	12	14	16
	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
400	½	1	1½	2	2½	3	4	5	6	7	8
600	¾	1½	2¼	3	3¾	4½	6	7½	9	10½	12
800	1	2	3	4	5	6	8	10	12	14	16
1000	1¼	2½	3¾	5	6¼	7½	10	12½	15	17½	20
1200	1½	3	4½	6	7½	9	12	15	18	21	24
1500	1⅞	3¾	5¾	7½	9½	11	15	18¾	22	26½	30
1800	2¼	4½	6¾	9	11¼	13	18	22½	27	31½	36
2000	2½	5	7½	10	12½	15	20	25	30	35	40
2400	3	6	9	12	15	18	24	30	36	42	48
2800	3½	7	10	14	17	21	28	35	42	49	56
3000	3¾	7½	11	15	18	22	30	37	45	52	60
3500	4¼	8¾	13	17½	22	26	35	44	52	61	70
4000	5	10	15	20	25	30	40	50	60	70	80
4500	5½	11	17	22	28	34	45	57	69	78	90
5000	6	12	19	25	31	37	50	62	75	87	100

Double leather, six-ply rubber or six-ply cotton belting will transmit about 60 per cent more power than is shown on this table. (One-inch wide, double, 550 feet per minute = one horse-power.)

UNIT OF HEAT

What is meant by the expression unit of heat?

A heat unit (B. t. u.) is the quantity of heat required to raise the temperature of one pound of water one degree, or from 39 degrees to 40 degrees F. The heat unit is used for calculating the quantity of heat contained in any form and know weight of matter.

The mechanical equivalent of heat, or rather of one heat unit, is 778 foot pounds. (A foot pound is one pound weight raised one foot high.)

How to calculate horsepower from the above data: One horsepower equals 33,000 lbs. raised one foot high in one minute of time. One heat unit equals 778 foot lbs. or 778 divided by 33,000 equals about 1-43 of a horsepower.

HORSEPOWER OF STEAM ENGINES

The rate at which steam does work upon the engine piston equals indicated horsepower, I. H. P. equals to average total pressure on piston, pounds, times distance moved by piston in feet per minute divided by 33,000. Also I. H. P. equals average effective pressure on piston, pounds, per square inch times (piston displacement, cubic inches, per minute) divided by 396,000.

$$\text{I. H. P.} = \frac{\text{M. E. P., lb. per sq. in.} \times \text{piston area, sq. in.} \times \text{piston speed, ft. per min.}}{33{,}000}$$

Also, $\text{I. H. P.} = \dfrac{PLAN}{33{,}000}$, where P equals mean indicated pressure, lbs. per square inch; L equals length of stroke, feet; A equals effective area of piston, square inches, after deducting area of piston rod or tail rod; N equals number of working strokes per minute. A horsepower equals 33,000 foot pounds per minute, or 1,980,000 foot pounds per hour, or 1,980,000 × 12 = 23,760,000 inch pounds per hour, meaning that the same amount of energy required to lift 33,000 pounds one foot high in one minute of time would lift 23,760,000 pounds one inch high in one minute of time.

ELECTRICAL HORSEPOWER

What constitutes one electrical horsepower? The current (C) in amperes multiplied by the electromotive force (E) in volts, divided by 746; expressed as follows:

$$\text{E. H. P.} = \frac{E \times C}{746}$$

It takes 1,000 watts, expressed as one kilowatt, to deliver one mechanical, or brake, horsepower in practice.

If the brake horsepower of an electric motor be known, how may the efficiency be calculated? By the following formula:

$$e = \frac{\text{B. H. P.} \times 746}{E \times C}$$

in which e equals efficiency; B. H. P. equals brake horsepower; E equals volts; C equals amperes.

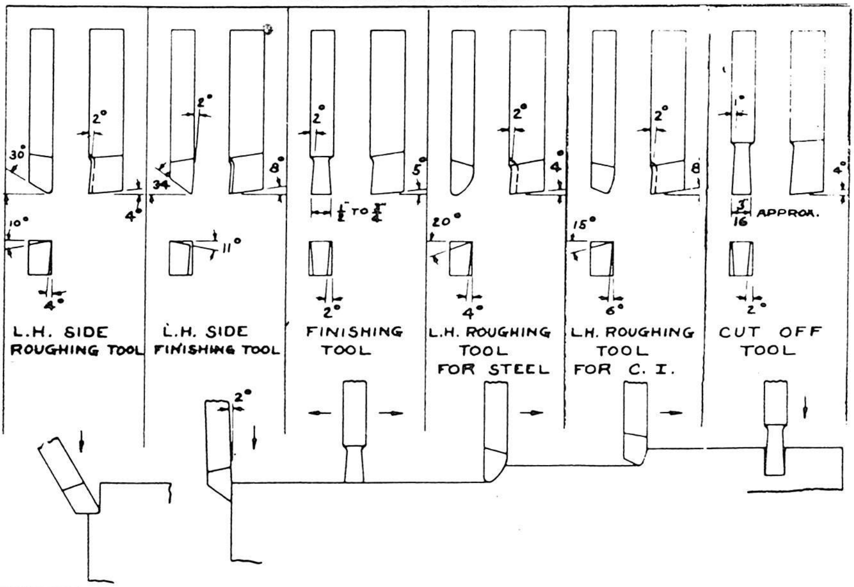
HORSEPOWER OF AN EXPLOSIVE MOTOR OR GASOLINE ENGINE

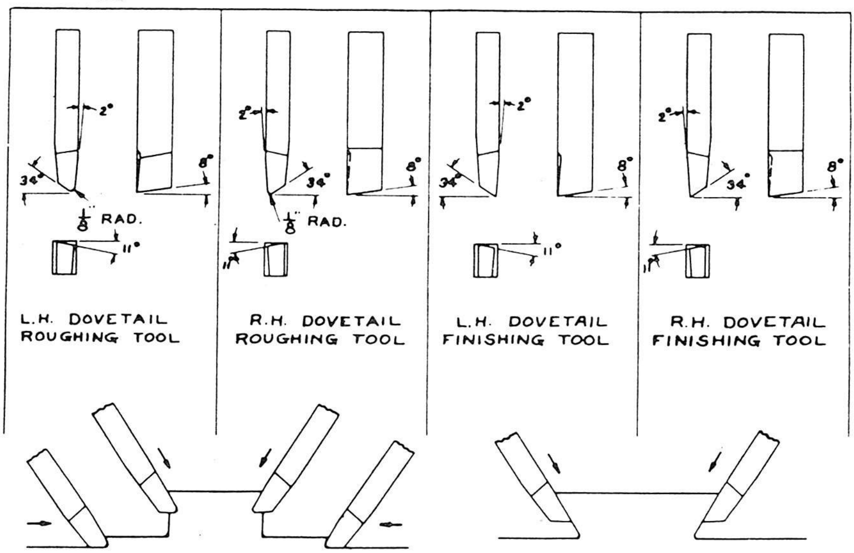
First ascertain the number of strokes per minute; then

$$\text{H. P.} = \frac{PLAN}{33{,}000}$$

in which H. P. equals horsepower; P equals mean effective pressure; L equals length of stroke in feet; A equals area of piston in square inches; N equal number of power strokes per minute.

CUTTING TOOLS RECOMMENDED FOR USE ON CINCINNATI SHAPERS





Thread-Cutting Data

No. of Threads per Inch	No. of Chasing Cuts
8	18
10	14
11	13
12	11
13	10
16	9
20	8

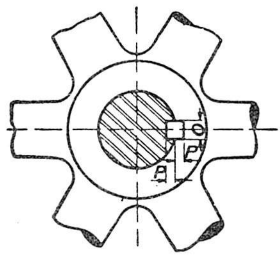
This table is based on .005″ per cut allowing an extra cut for finish which is the actual practice in our shop.

STANDARD *IXL* KEY SEATS

Strength of Sunk Keys — The strength of a sunk key is the measure of its holding power. A key of width w, thickness t, length l, all in inches, a unit shearing strength of fs, and unit crushing resistance of fc in lb. per square in. will have a shearing strength, lb. per sq. in., of fs wl and a crushing resistance fc (½tl.).

If r = radius of the shaft, in., the moment which the key can resist will be rwlfs or ½rtlfc, whichever is smaller.

Experiments made by Professor Lanza indicate that the ultimate value of fs for cast-iron = 30,000 lb., for wrought-iron = 40,000 lb., and for machinery steel = 60,000 lb. A factor of safety of 2 would be advisable with these values.



Diameter of Hole, Inches	O Width of Key Seat	P Depth of Key Seat	Diameter of Hole, Inches	O Width of Key Seat	P Depth of Key Seat
3/8	3/32	3/64	3 1/4 to 3 11/16	7/8	7/16
7/16 to 1/2	1/8	1/16	3 3/4 to 4 3/16	1	1/2
9/16 to 5/8	5/32	5/64	4 1/4 to 4 11/16	1 1/8	9/16
11/16 to 3/4	3/16	3/32	4 3/4 to 5 3/16	1 1/4	5/8
13/16 to 7/8	7/32	7/64	5 1/4 to 5 11/16	1 3/8	11/16
15/16 to 1 1/8	1/4	1/8	5 3/4 to 6 3/16	1 1/2	3/4
1 3/16 to 1 3/8	5/16	5/32	6 1/4 to 6 11/16	1 5/8	13/16
1 7/16 to 1 5/8	3/8	3/16	6 3/4 to 7 3/16	1 3/4	7/8
1 11/16 to 1 7/8	7/16	7/32	7 1/4 to 7 11/16	1 7/8	15/16
1 15/16 to 2 1/8	1/2	1/4	7 3/4 to 8 3/16	2	1
2 3/16 to 2 11/16	5/8	5/16	8 1/4 to 8 15/16	2 1/8	1 1/16
2 3/4 to 3 3/16	3/4	3/8	9 to 10	2 1/4	1 1/8

Reaming in the Lathe

Reamers are used in the lathe to finish a number of holes quickly and accurately to the same diameter. Usually the hole is first drilled or bored roughly to size, allowing sufficient stock for reaming. Two types of reamers are used, the rose reamer and the fluted reamer.

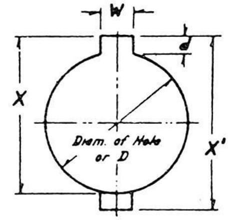
Rose reamers are ground for cutting on the end only and are intended for rough reaming as they do not produce a good finish or an accurate diameter.

Fluted reamers are ground for cutting on both the ends and the sides of the blades and are usually used after the rose reamer to obtain an exact size and produce a good smooth finish. Fluted reamers should be used only for light cuts, removing not over .010 in. from the hole.

DIMENSIONS OF STANDARD KEY-SEATS AND SETSCREWS FOR GEARS

IN INCHES

Diam. of Hole	Key-seat W	Key-seat d	Set-screw	Diam. of Hole	Key-seat W	Key-seat d	Set-screw
1/4 to 3/8	1/16	1/32	10-32	3 7/8 to 5 3/16	1	1/2	1-8
7/16 to 5/8	1/8	1/16	1/4-20	5 1/4 to 6 7/16	1 1/8	9/16	1 1/8-7
1/16 to 7/8	3/16	3/32	5/16-18	6 1/2 to 7 11/16	1 1/4	5/8	..
15/16 to 1 1/8	1/4	1/8	3/8-16	7 3/4 to 8 15/16	1 3/8	11/16	..
1 3/16 to 1 5/16	5/16	5/32	7/16-14	9 to 10 3/16	1 1/2	3/4	..
1 3/8 to 1 13/16	3/8	3/16	1/2-13	10 1/4 to 11 7/16	1 5/8	13/16	..
1 7/8 to 2 5/16	1/2	1/4	9/16-12	11 1/2 to 12 11/16	1 3/4	7/8	..
2 3/8 to 2 13/16	5/8	5/16	5/8-11	12 3/4 to 13 15/16	1 7/8	15/16	..
2 7/8 to 3 5/16	3/4	3/8	3/4-10	14 to 14 15/16	2	1	..
3 3/8 to 3 13/16	7/8	7/16	7/8-9				



Formula

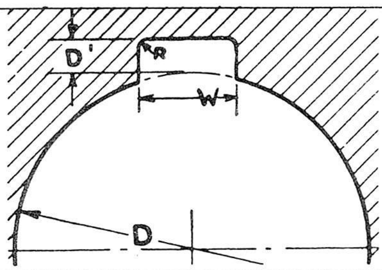
$$X = \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{W}{2}\right)^2} + d + \frac{D}{2}$$

$$X' = 2X - D$$

Example

Hole 1"; Keyway 1/4" wide by 1/8" deep.

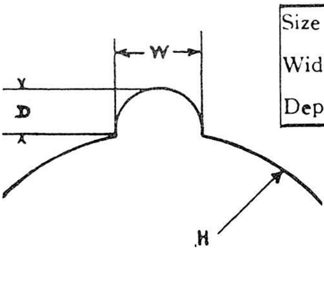
$$X = \sqrt{\left(1/2\right)^2 - \left(1/8\right)^2} + 1/8 + 1/2 = 1109''$$



STANDARD KEYWAYS FOR CUTTERS

Diam. (D) of Hole, Inches	Width (W) of Keyway, In.	Depth (D') of Keyway, In.	Radius (R), Inches
1-2	3-32	3-64	1-64
5-8	1-8	1-16	1-32
3-4	1-8	1-16	1-32
7-8	1-8	1-16	1-32
1	1-4	3-32	3-64
1 1-4	5-16	1-8	3-64
1 1-2	3-8	5-32	1-16
1 3-4	7-16	3-16	1-16
2	1-2	3-16	1-16
2 1-4	5-8	7-32	1-16
2 1-2	5-8	7-32	1-16
2 3-4	3-4	1-4	1-16

HALF ROUND KEYWAY



Size Hole, H	3/8-5/8	11/16-13/16	7/8-1 3/16	1 1/4-1 7/16	1 1/2-2	2 1/16-2 7/16	2 1/2-3
Width, W	1/8	3/16	1/4	5/16	3/8	7/16	1/2
Depth, D	1/16	3/32	1/8	5/32	3/16	7/32	1/4

U. S. NAVY STANDARD KEYS

Keys and Keyways for Propellers
Proportions of Sunk Keys

Shaft Diam. Inch	Key Width Inch	Key Thickness Inch	Shaft Diam. Inch	Key Width Inch	Key Thickness Inch	Shaft Diam. Inch	Key Width Inch	Key Inch Thickness
1/2	7/32	3/16	3	11/16	7/16	6 3/4	1 3/8	3/4
5/8	1/4	3/16	3 1/4	3/4	7/16	7	1 7/16	13/16
3/4	9/32	3/16	3 1/2	13/16	7/16	7 1/4	1 1/2	13/16
7/8	9/32	7/32	3 3/4	13/16	1/2	7 1/2	1 9/16	7/8
1	5/16	7/32	4	7/8	1/2	7 3/4	1 9/16	7/8
1 1/8	11/32	1/4	4 1/4	15/16	9/16	8	1 5/8	7/8
1 1/4	3/8	1/4	4 1/2	1	9/16	8 1/4	1 5/8	15/16
1 3/8	3/8	1/4	4 3/4	1	9/16	8 1/2	1 3/4	15/16
1 1/2	13/32	1/4	5	1 1/16	5/8	8 3/4	1 3/4	15/16
1 3/4	7/16	5/16	5 1/4	1 1/8	5/8	9	1 3/4	1
2	1/2	5/16	5 1/2	1 3/16	5/8	9 1/4	1 7/8	1
2 1/4	9/16	5/16	5 3/4	1 3/16	11/16	9 1/2	1 7/8	1 1/16
2 1/2	5/8	3/8	6	1 1/4	11/16	9 3/4	2	1 1/16
2 3/4	5/8	3/8	6 1/4	1 5/16	3/4	10	2	1 1/16
			6 1/2	1 3/8	3/4			

Sunk Keys are generally proportioned with relation to the Shaft Diameter, instead of considering the torsional lead in each case, because rules which apply to sunk keys have been used widely. It is best however, to proportion keys according to an adopted standard.

RULE 1—The width of the key equals 1/4 of the Shaft Diameter; the thickness 1/6 of the Shaft Diameter; the minimum length 1 1/2 times the Shaft Diameter. In the following W = Key Width; T = Key Thickness; L = Key Length; and D = Shaft Diam.

$$W = \frac{D}{4} \qquad T = \frac{1}{6} D \qquad L = 1.5\,D$$

RULE 2 — $W = \frac{3}{16} D + \frac{1}{16}$ inch; $T = \frac{1}{8} D + \frac{1}{8}$ inch; $L = \frac{3}{10} D^2 \div T$

For Splines or Feather Keys, interchange the dimensions for width and thickness.

RULE 3 (Unwin) — $W = \frac{1}{4} D + \frac{1}{8}$ inch; $T = \frac{1}{8} D + \frac{1}{8}$ inch.

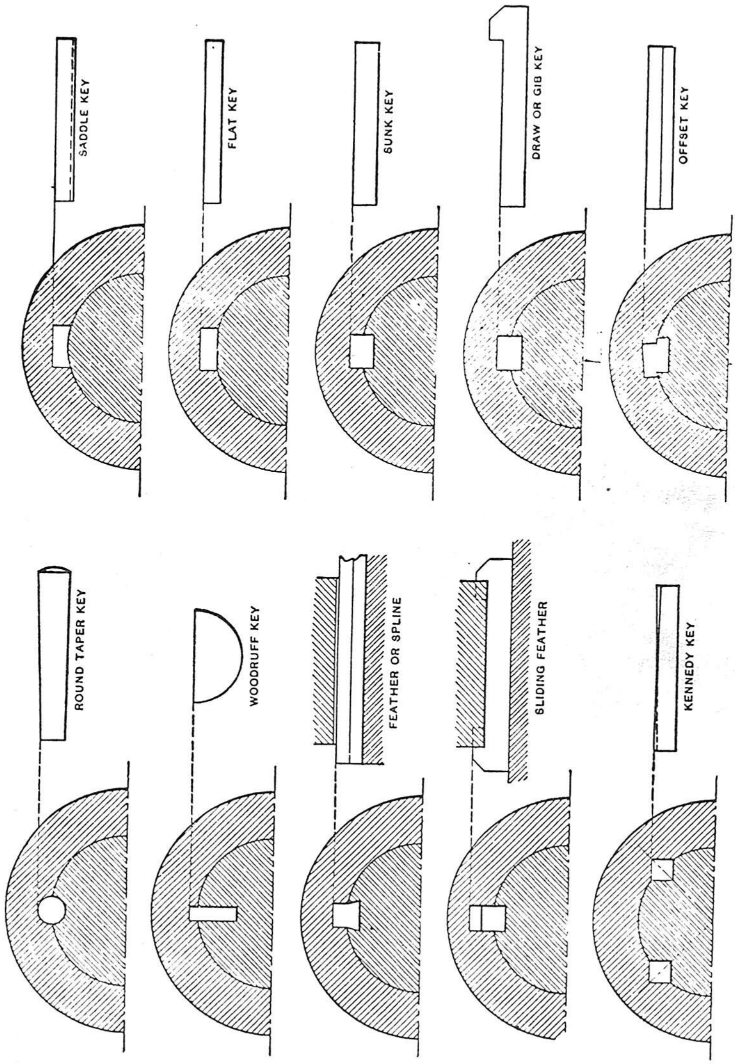
When gears or pulleys transmitting only a small amount of power are keyed to large shafts, these dimensions are excessive.

The taper of sunk keys is usually about 1/8 or 3/16 inch per foot. The depth of a taper keyseat at the deep end should be 3/5 of the key thickness.

The U. S. Navy, in proportioning keys for Propellers, is to make the width of the key about 1 1/2 times its thickness. The thickness, in turn, is so determined that the side pressure on the propeller hub, calculated from the maximum turning moment on the shaft, does not exceed 25,000 pounds per square inch. The key is so proportioned that the pressure on the keyway will not exceed 22,000 pounds per square inch. With this pressure, if the key thickness is over 1/8 of the Shaft Diameter, two keys, set opposite, are preferred.

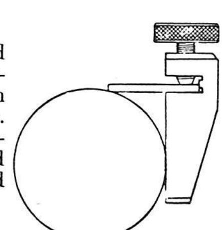
The Hub of the Propeller is bored, tapered and fitted to a corresponding taper on the shaft, which is provided with a retaining nut.

Different Types of Keys used



Key Seat Clamps

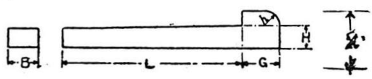
For laying out keyways and scribing parallel lines on circular pieces. Easily put on and taken off of steel rules. Can be used also on combination square blades and straight edges (except Beveled Steel Straight Edges).



GIB KEYS DIMENSIONS

$G=B$, approximately;
$H=\frac{1}{6}$ times diam. of bore up to 6 inches; for larger sizes, $H=\frac{1}{8}\times$bore;
h=radius$=\frac{1}{8}$ times diam. of bore, approx., but minimum value$=\frac{3}{16}$ inch,
L=length of hub$+\frac{1}{2}$ inch.
Taper $\frac{1}{8}$ inch per foot.

R=radius of shaft;
B=breadth of key;
S=safe shearing strength of material in key;
$B=\frac{1}{4}$ times diam. of bore, up to 6 inches; for larger sizes, $B=0.211\times$bore, approximately;

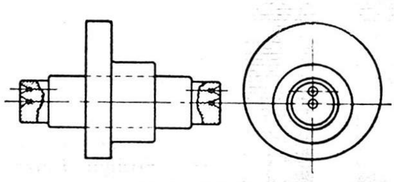


Keys of proportions given below are weakest in shear.
The safe twisting moment per inch of length of keys $=R\times B\times S$

Bore and Shaft Diameter	Width of Key B	Height of Key H	Depth of Key-way $\frac{H}{2}$	Rad. h	G	Safe Twisting Moment on Key per Inch of Length f or $S=$ 5000	7500	10,000
$\frac{15}{16}$ to $1\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{32}$	$\frac{3}{16}$	$\frac{1}{4}$	630	940	1,250
$1\frac{3}{16}$ to $1\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{3}{8}$	1,170	1,760	2,340
$1\frac{7}{16}$ to $1\frac{5}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{3}{8}$	1,410	2,110	2,810
$1\frac{11}{16}$ to $1\frac{7}{8}$	$\frac{1}{2}$	$\frac{5}{16}$	$\frac{5}{32}$	$\frac{1}{4}$	$\frac{1}{2}$	2,190	3,280	4,380
$1\frac{15}{16}$ to $2\frac{1}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{2}$	2,500	3,750	5,000
$2\frac{3}{16}$ to $2\frac{3}{8}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{5}{8}$	3,520	5,270	7,030
$2\frac{7}{16}$ to $2\frac{5}{8}$	$\frac{5}{8}$	$\frac{7}{16}$	$\frac{7}{32}$	$\frac{3}{8}$	$\frac{5}{8}$	3,910	5,860	7,810
$2\frac{11}{16}$ to $2\frac{7}{8}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{4}$	5,160	7,730	10,313
$2\frac{15}{16}$ to $3\frac{1}{8}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{4}$	5,620	8,420	11,250
$3\frac{3}{16}$ to $3\frac{3}{8}$	$\frac{7}{8}$	$\frac{9}{16}$	$\frac{9}{32}$	$\frac{1}{2}$	$\frac{7}{8}$	7,110	10,660	14,220
$3\frac{7}{16}$ to $3\frac{5}{8}$	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{5}{16}$	$\frac{1}{2}$	$\frac{7}{8}$	7,660	11,480	15,310
$3\frac{11}{16}$ to $3\frac{7}{8}$	1	$\frac{5}{8}$	$\frac{5}{16}$	$\frac{1}{2}$	1	9,380	14,060	18,750
$3\frac{15}{16}$ to $4\frac{1}{8}$	1	$\frac{11}{16}$	$\frac{11}{32}$	$\frac{1}{2}$	1	10,000	15,000	20,000
$4\frac{3}{16}$ to $4\frac{3}{8}$	$1\frac{1}{8}$	$\frac{11}{16}$	$\frac{11}{32}$	$\frac{5}{8}$	1	11,950	17,930	23,910
$4\frac{7}{16}$ to $4\frac{3}{4}$	$1\frac{1}{8}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{5}{8}$	1	12,660	18,980	25,310
$4\frac{13}{16}$ to $5\frac{1}{4}$	$1\frac{1}{4}$	$\frac{7}{8}$	$\frac{7}{16}$	$\frac{5}{8}$	$1\frac{1}{4}$	15,620	23,440	31,250
$5\frac{5}{16}$ to $5\frac{3}{4}$	$1\frac{3}{8}$	$\frac{7}{8}$	$\frac{7}{16}$	$\frac{3}{4}$	$1\frac{1}{4}$	18,910	28,360	37,810
$5\frac{13}{16}$ to $6\frac{1}{4}$	$1\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{2}$	22,500	33,750	45,000
$6\frac{5}{16}$ to $6\frac{3}{4}$	$1\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{7}{8}$	$1\frac{1}{2}$	24,380	36,560	48,750
$6\frac{13}{16}$ to $7\frac{1}{4}$	$1\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{7}{8}$	$1\frac{3}{4}$	26,250	39,380	52,500
$7\frac{5}{16}$ to $7\frac{3}{4}$	$1\frac{5}{8}$	1	$\frac{1}{2}$	1	$1\frac{3}{4}$	30,470	45,700	60,940
$7\frac{13}{16}$ to $8\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{1}{8}$	$\frac{9}{16}$	1	2	36,090	54,140	72,190
$8\frac{13}{16}$ to $9\frac{3}{4}$	2	$1\frac{1}{4}$	$\frac{5}{8}$	$1\frac{1}{8}$	2	46,250	69,380	92,500
$9\frac{13}{16}$ to $10\frac{3}{4}$	$2\frac{1}{4}$	$1\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	2	57,660	86,480	115,320
$10\frac{13}{16}$ to $11\frac{3}{4}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	2	70,310	105,470	140,630
$11\frac{13}{16}$ to $12\frac{3}{4}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	2	76,560	114,840	153,130

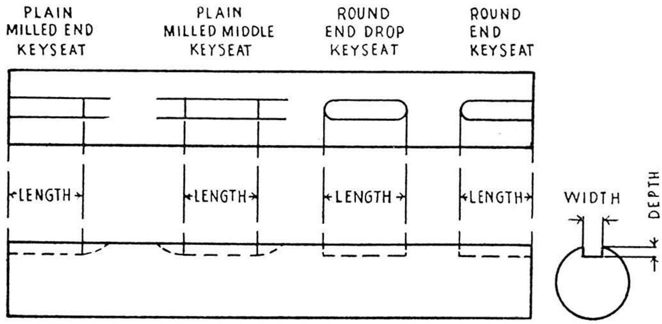
Machining Eccentrics

A simple eccentric can be machined on a straight mandrel having two sets of center holes as shown in Fig. 1. One set of centers is used for machining the concentric hub and the other set of centers is used for machining the eccentric part.



A Mandrel with Two Sets of Center Holes for Machining an Eccentric

KEYSEATS IN SHAFTING



DIMENSIONS

Shaft Diameter, Inches	Width Keyseat, Inches	Depth Keyseat, Inches		Shaft Diameter, Inches	Width Keyseat, Inches	Depth Keyseat, Inches	
		Square Key	Flat Key			Square Key	Flat Key
1/2	1/8	1/16	3/64	2 3/8	5/8	5/16	7/32
9/16	1/8	1/16	3/64	2 7/16	5/8	5/16	7/32
5/8	3/16	3/32	1/16	2 1/2	5/8	5/16	7/32
11/16	3/16	3/32	1/16	2 5/8	5/8	5/16	7/32
3/4	3/16	3/32	1/16	2 3/4	5/8	5/16	7/32
13/16	3/16	3/32	1/16	2 7/8	3/4	3/8	1/4
7/8	3/16	3/32	1/16	2 15/16	3/4	3/8	1/4
15/16	1/4	1/8	3/32	3	3/4	3/8	1/4
1	1/4	1/8	3/32	3 1/8	3/4	3/8	1/4
1 1/16	1/4	1/8	3/32	3 1/4	3/4	3/8	1/4
1 1/8	1/4	1/8	3/32	3 3/8	7/8	7/16	5/16
1 3/16	1/4	1/8	3/32	3 7/16	7/8	7/16	5/16
1 1/4	1/4	1/8	3/32	3 1/2	7/8	7/16	5/16
1 5/16	5/16	5/32	1/8	3 5/8	7/8	7/16	5/16
1 3/8	5/16	5/32	1/8	3 3/4	7/8	7/16	5/16
1 7/16	3/8	3/16	1/8	3 7/8	1	1/2	3/8
1 1/2	3/8	3/16	1/8	3 15/16	1	1/2	3/8
1 9/16	3/8	3/16	1/8	4	1	1/2	3/8
1 5/8	3/8	3/16	1/8	4 1/4	1	1/2	3/8
1 11/16	3/8	3/16	1/8	4 7/16	1	1/2	3/8
1 3/4	3/8	3/16	1/8	4 1/2	1	1/2	3/8
1 13/16	1/2	1/4	3/16	4 3/4	1 1/4	5/8	7/16
1 7/8	1/2	1/4	3/16	4 15/16	1 1/4	5/8	7/16
1 15/16	1/2	1/4	3/16	5	1 1/4	5/8	7/16
2	1/2	1/4	3/16	5 1/4	1 1/4	5/8	7/16
2 1/16	1/2	1/4	3/16	5 7/16	1 1/4	5/8	7/16
2 1/8	1/2	1/4	3/16	5 1/2	1 1/4	5/8	7/16
2 3/16	1/2	1/4	3/16	5 3/4	1 1/2	3/4	1/2
2 1/4	1/2	1/4	3/16	5 15/16	1 1/2	3/4	1/2
2 5/16	5/8	5/16	7/32	6	1 1/2	3/4	1/2

Unless otherwise specified all Keyseats will be made with Cutter Runouts. Round End Keyseats will be furnished only when designated. Be sure to specify Round End for Keyseat ends coming next to bearings.

U. S. STANDARD STEAM, GAS AND WATER PIPE

Size of Pipe Tap	Threads per Inch	Outside Diam. of Pipe	Inside Diam. of Pipe	Total Length of Thread	Length of Perfect Thread	Size of Tap Drill	Diam. at End of Pipe: Outside	Diam. at End of Pipe: At Bott. of Thd.
1/8	27	.405	.270	.41	.19	21-64	.393	.342
1/4	18	.540	.364	.62	.29	29-64	.522	.445
3/8	18	.675	.494	.63	.30	19-32	.656	.579
1/2	14	.840	.623	.83	.39	23-32	.816	.717
3/4	14	1.050	.824	.84	.40	15-16	1.025	.926
1	11 1/2	1.315	1.048	1.03	.51	1 3-16	1.283	1.162
1 1/4	11 1/2	1.660	1.380	1.06	.54	1 15-32	1.626	1.505
1 1/2	11 1/2	1.900	1.611	1.07	.55	1 23-32	1.866	1.745
2	11 1/2	2.375	2.067	1.10	.58	2 3-16	2.339	2.218
2 1/2	8	2.875	2.468	1.64	.89	2 11-16	2.819	2.646
3	8	3.500	3.067	1.70	.95	3 5-16	3.441	3.268
3 1/2	8	4.000	3.548	1.75	1.00	3 13-16	3.938	3.765
4	8	4.500	4.026	1.80	1.05	4 7-32	4.434	4.261
4 1/2	8	5.000	4.508	1.85	1.10	4 21-32	4.931	4.758
5	8	5.563	5.045	1.91	1.16	5 15-64	5.491	5.318
6	8	6.625	6.065	2.01	1.26	6 1-4	6.546	6.373
7	8	7.625	7.023	2.11	1.36	7 5-16	7.540	7.367
8	8	8.625	7.982	2.21	1.46	8 5-16	8.534	8.361
9	8	9.625	8.937	2.32	1.57	9 5-16	9.527	9.354
10	8	10.750	10.019	2.43	1.68	10 5-16	10.645	10.472

Note—The Taper of the Threaded Part is 1 in 16

STANDARD DIMENSIONS OF COUPLINGS

Nom. Inside Dia. of Pipe	Inside Diam.	Outside Diam.	Length	Threads Per Inch	Nom. Inside Dia. of Pipe	Inside Diam.	Outside Diam.	Length	Threads Per Inch
1/8	11/32	19/32	13/16	27	4	4 17/64	5	3 5/8	8
1/4	15/32	23/32	15/16	18	4 1/2	4 3/4	5 1/2	3 5/8	8
3/8	37/64	27/32	1 1/16	18	5	5 9/32	6 7/32	4 1/8	8
1/2	23/32	1	1 5/16	14	6	6 11/32	7 5/16	4 1/8	8
3/4	63/64	1 21/64	1 9/16	14	7	7 3/8	8 5/16	4 1/8	8
1	1 11/64	1 9/16	1 13/16	11 1/2	8	8 3/8	9 5/16	4 5/8	8
1 1/4	1 1/2	1 61/64	2 1/8	11 1/2	9	9 7/16	10 3/8	5 1/8	8
1 1/2	1 3/4	2 7/32	2 3/8	11 1/2	10	10 7/16	11 21/32	6 1/8	8
2	2 7/32	2 3/4	2 5/8	11 1/2	11	11 15/32	12 21/32	6 1/8	8
2 1/2	2 21/32	3 9/32	2 7/8	8	12	12 7/16	13 7/8	6 1/8	8
3	3 1/4	3 15/16	3 1/8	8	13	13 11/16	15 1/16	6 1/8	8
3 1/2	3 25/32	4 7/16	3 5/8	8	14	14 23/32	16 3/8	6 1/8	8
					15	15 11/16	17 3/8	6 1/8	8

BRIGGS PIPE STANDARD

Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.
1/8-27	R	1/2-14	23/32	1 1/4-11 1/2	1 1/2	2 1/2-8	2 5/8
1/4-18	7/16	3/4-14	59/64	1 1/2-11 1/2	1 47/64	3 -8	3 1/4
3/8-18	37/64	1 -11 1/2	1 5/32	2 -11 1/2	2 7/32	....	....

Standard Dimensions for Nipples

Pipe Size	Close	Short	Length in Inches Long			
1/8	3/4	1 1/2	2	2 1/2	3	3 1/2
1/4	7/8	1 1/2	2	2 1/2	3	3 1/2
3/8	1	1 1/2	2	2 1/2	3	3 1/2
1/2	1 1/8	1 1/2	2	2 1/2	3	3 1/2
3/4	1 3/8	2	2 1/2	3	3 1/2	4
1	1 1/2	2	2 1/2	3	3 1/2	4
1 1/4	1 5/8	2 1/2	3	3 1/2	4	4 1/2
1 1/2	1 3/4	2 1/2	3	3 1/2	4	4 1/2
2	1 3/4	2 1/2	3	3 1/2	4	4 1/2
2 1/2	2 1/2	3	3 1/2	4	4 1/2	5
3	2 5/8	3	3 1/2	4	4 1/2	5
3 1/2	2 3/4	4	4 1/2	5	5 1/2	6
4	3	4	4 1/2	5	5 1/2	6
4 1/2	3	4	4 1/2	5	5 1/2	6
5	3 1/2	4 1/2	5	5 1/2	6	6 1/2
6	3 1/2	4 1/2	5	5 1/2	6	6 1/2
7	3 1/2	5				6
8	3 1/2	5				6
9	4	5			6	8
10	4	5			6	8
11	4	5			6	8
12	4	5			6	8

CAST IRON PIPES

Nominal Weight of a Lineal Foot, Without Flanges

Bore in Inches	Thickness of Metal in Inches								
	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2	5.52	8.74	12.27	16.11	20.25	24.70	29.45	34.52	39.88
2 1/2	6.75	10.58	14.73	19.18	23.95	28.99	34.36	40.04	46.02
3	7.93	12.43	17.18	22.24	27.61	32.29	39.27	45.56	52.16
3 1/2	9.20	14.27	19.64	25.31	31.29	37.58	41.18	51.08	58.29
4	10.43	16.11	22.09	28.38	34.98	41.88	49.09	56.60	64.43
4 1/2	11.66	17.95	24.54	31.45	38.66	46.18	54.00	62.13	70.56
5	12.89	19.79	27.00	34.52	42.34	50.47	58.91	67.65	76.70
5 1/2	14.11	21.63	29.45	37.58	46.02	54.76	63.81	73.17	82.84
6	15.34	23.47	31.91	40.65	49.70	59.06	68.72	78.69	88.97
7	17.79	27.15	36.82	46.79	57.06	67.65	78.54	89.74	101.24
8	20.25	30.83	41.72	52.92	64.43	76.24	88.36	100.78	113.52
9	22.70	34.52	46.63	59.06	71.79	84.83	98.18	111.83	125.79
10	25.16	38.20	51.54	65.19	79.15	93.42	107.99	122.87	138.06
11	27.61	41.88	56.45	71.33	86.52	102.01	117.81	133.92	150.33
12	30.07	46.56	61.36	77.47	93.88	110.60	127.63	144.96	162.60
13	32.52	49.24	66.27	83.60	101.24	119.19	137.45	156.01	174.87
14	34.98	52.92	71.18	89.74	108.61	127.78	147.26	167.06	187.15
15		56.60	76.09	95.87	115.97	136.37	157.08	178.10	199.42
16		60.29	80.99	102.01	123.33	144.96	166.90	189.14	211.69
18		67.66	90.81	114.28	138.06	162.14	186.53	211.23	236.23
20			100.63	126.55	152.79	179.32	206.17	233.32	260.78
22			110.45	138.83	167.51	196.50	225.80	255.41	285.32
24			120.28	151.10	182.24	213.68	245.44	277.50	309.87

LEAD PIPE AND CALKING LEAD

For several years buyers of lead pipe and lead for calking have had the same protection as buyers of lead fittings. Rigid industry standards control the manufacture of these items and the Lead Industries' Seal of Approval readily identifies products meeting the standards. The purity of metal is carefully guarded by definite limitation of impurities and manufacturing defects are prohibited. Specific tolerances are provided for wall thickness and concentricity of pipe. Pipe meeting the standard must be stamped at least every 24 in. with the manufacturer's name or identification mark and the Seal of Approval, and each length or coil with the inside diameter and symbol for weight at least once. Calking lead must also have the manufacturer's name or identification mark cast or stamped on each piece, or in the case of lead wool, where impossible, it must appear on the package or tag.

LEAD PIPE STANDARD

Inside Diameter In.	Classification East	Classification West	Outside Diameter In.	Weight Per Foot Lb.	Weight Per Foot Oz.
3/8	D	XL	.540		10
	C	L	.577		12
	B	M	.631	1	
	A	S	.725	1	8
	AA	XS	.811	2	
	AAA	XXS	.888	2	8
1/2	D	XL	.666		12
	C	L	.712	1	
	B	M	.756	1	4
	A	S	.798	1	8
	AA	XS	.876	2	
	AAA	XXS	1.012	3	
5/8	D	XL	.803	1	
	C	L	.881	1	8
	B	M	.953	2	
	A	S	1.019	2	8
	AA	XS	1.082	3	
	AAA	XXS	1.137	3	8
3/4	D	XL	.940	1	4
	C	L	1.006	1	12
	B	M	1.068	2	4
	A	S	1.156	3	
	AA	XS	1.212	3	8
	AAA	XXS	1.336	4	12
1	D	XL	1.232	2	
	C	L	1.284	2	8
	B	M	1.356	3	4
	A	S	1.428	4	
	AA	XS	1.492	4	12
	AAA	XXS	1.596	6	
1 1/4	D	XL	1.486	2	8
	C	L	1.528	3	
	B	M	1.592	3	12
	A	S	1.670	4	12
	AA	XS	1.765	6	
	AAA	XXS	1.889	7	12
1 1/2	D	XL	1.776	3	8
	C	L	1.830	4	4
	B	M	1.882	5	
	A	S	1.984	6	8
	AA	XS	2.076	8	
	AAA	XXS	2.272	11	4
1 3/4	D	XL	2.024	4	
	C	L	2.086	5	
	B	M	2.146	6	
	A	S	2.193	6	12
	AA	XS	2.404	10	8
	AAA	XXS	2.621	14	12
2	D	XL	2.284	4	12
	C	L	2.354	6	
	B	M	2.410	7	
	A	S	2.503	8	12
	AA	XS	2.751	13	12
	AAA	XXS	3.008	19	8
2 1/2			2.75	5	
			3.00	10	10
3			3.25	6	
			3.50	12	8
4			4.25	7	14
			4.50	16	6
5			5.25	9	11
			5.50	20	4
6			6.25	11	13
			6.50	24	2

RECOMMENDED PIPE WEIGHTS

PURPOSES	CLASSIFICATION East	CLASSIFICATION West
For plumbing soil, waste and vent pipes	D or C	XL or L
For chemical waste pipes	B	M
For water pipes:		
Constant cold water pressures up to 50 lb. per sq. in.	A	S
Constant cold water pressures up to 75 lb. per sq. in.	AA	XS
Constant cold water pressures up to 100 lb. per sq. in.	AAA	XXS

In sizes above 2 in. inside diameter, there is no classification marking. The lighter of the two weights listed in each size is for plumbing soil, waste and vent pipes, and the heavier weight for chemical wastes.

CALKING LEAD STANDARD

Lead for calking purposes shall contain not less than 99.73 per cent pure lead. Impurities shall not exceed the following limits:

Arsenic, Antimony and Tin together	0.015 per cent
Copper	0.08 per cent
Zinc	0.002 per cent
Iron	0.002 per cent
Bismuth	0.25 per cent
Silver	0.02 per cent

WEIGHT COMPUTING FORMULAS

Round Hot Rolled or Cold Drawn Seamless Steel Tubing

To determine the average wall weight of a tube:

$$W = 10.68\,(D - t)\,t$$

To determine the minimum wall weight of a tube:

$$W = 10.68\left(D - \frac{t}{.875}\right)\frac{t}{.875}$$

Where W = Weight in pounds per foot (carried to 4 digits)
D = Outside Diameter in inches (to 3 decimal places)
t = Wall thickness in decimals (to 3 decimal places)

All weights are carried to four digits only, the fifth digit being carried forward if five or over, or dropped if under five.

Outside diameters and wall thicknesses are carried to three decimal places, the fourth decimal being carried forward if five or over, or dropped if under five.

Hot Rolled and Cold Finished Steel Products

Product	When Shown As			Single Weight Formulas
	Thickness	Width	Length	
Structurals and Bar Shapes	Wt. per Ft.	Inches	Feet	Wt./Lin. Ft.xL
	Inches	Inches	Feet	Wt./Lin. Ft.xL
Plates, Strip and Flats	Inches	Inches	Inches	.2833xTxWxL
	Inches	Inches	Feet	3.4xTxWxL
	Inches	Feet	Feet	40.8xTxWxL
	USS. Ga. No.	Feet	Feet	Wt./Sq.Ft.xWxL
	Wt. per Sq. Ft.	Feet	Feet	Wt./Sq.Ft.xWxL
Hot and C.R. Sheets	Inches	Inches	Inches	.2904xTxWxL
	Inches	Inches	Feet	3.485xTxWxL
	Inches	Feet	Feet	41.82xTxWxL
	USS. Ga. No.	Feet	Feet	Wt./Sq.Ft.xWxL
	Wt. per Sq. Ft.	Feet	Feet	Wt./Sq.Ft.xWxL
	Thickness	Diameter		
Plate Circles	Inches	Inches		$.2225xTxD^2$
	Inches	Feet		$32.05xTxD^2$
Sheet Circles	Inches	Inches		$.228xTxD^2$
	Inches	Feet		$32.85xTxD^2$
	Diameter	Length		
Bars — Square	Inches	Feet		$3.4xD^2xL$
Bars — Round	Inches	Feet		$2.67xD^2xL$
Bars — Hexagon	Inches	Feet		$2.945xD^2xL$
Bars — Octagon	Inches	Feet		$2.817xD^2xL$
	Thickness	Outer Diameter	Length	
Tubing	Inches	Inches	Feet	10.68x(D-T)xTxL

Symbols Used in Above Formulas Refer to the Following:

T. .... Thickness L. .... Length
W. .... Width D. .... Diameter
Wt./Sq. Ft..... Weight per Square Foot in Pounds

BRITISH STANDARD PIPE FLANGES

As Published by the ENGINEERING STANDARDS COMMITTEE

For Steam Pressure Up to 55 Lbs. For Water Pressure Up to 200 Lbs. Sq. Inch

Internal Diameter of Pipe	Diameter of Flange	Diameter of Bolt Circle	Number of Bolts	Diameter of Bolts	THICKNESS OF FLANGE: Cast Iron and Steel or Iron Welded on	Cast Steel and Bronze	Stamped or Forged Wrought Iron or Steel
Inch	In.	In.		In.	In.	In.	In.
½	3¾	2⅝	4	½	½	⅜	3/16
¾	4	2⅞	4	½	½	⅜	3/16
1	4½	3¼	4	½	½	⅜	3/16
1¼	4¾	3 7/16	4	½	⅝	½	¼
1½	5¼	3⅞	4	½	⅝	½	¼
2	6	4½	4	⅝	¾	9/16	5/16
2½	6½	5	4	⅝	¾	9/16	5/16
3	7¼	5¾	4	⅝	¾	9/16	⅜
3½	8	6½	4	⅝	¾	9/16	⅜
4	8½	7	4	⅝	⅞	11/16	⅜
4½	9	7½	8	⅝	⅞	11/16	7/16
5	10	8¼	8	⅝	⅞	11/16	½
6	11	9¼	8	⅝	⅞	11/16	½
7	12	10¼	8	⅝	1	¾	½
8	13¼	11½	8	⅝	1	¾	½
9	14½	12¾	8	⅝	1	¾	⅝
10	16	14	8	¾	1	¾	⅝
11	17	15	8	¾	1⅛	⅞	⅝
12	18	16	12	¾	1⅛	⅞	⅝

Bolt Holes, for ½ inch and ⅝ inch, the diameter of the holes to be 1/16 inch larger than the diameter of the bolts, and for the larger sizes of bolts ⅛ inch. Bolt holes to be drilled off center lines.

The above table does not apply to boiler feed pipes, or to other water pipes subject to exceptional shocks.

For Steam Pressures Up to 125 Lbs., 225 Lbs. and 325 Lbs. per Square Inch

Internal Diameter of Pipe	Diam. of Flange 125 lb. 225 lb. 325 lb.	Diam. of Bolt Circle 125 lb. 225 lb. 325 lb.	Number of Bolts 125 lb. 225 lb. 325 lb.	Diameter of Bolts 125 lb. 225 lb.	Diameter of Bolts 325 lb.	THICKNESS OF FLANGES: Cast Iron and Steel or Iron Welded on 125 lb.	225 lb.	325 lb.	Steel (Cast or Riveted on) and Bronze 125 lb.	225 lb.	325 lb.
½	3¾	2⅝	4	½	½	½	½	⅝	⅜	7/16	⅝
¾	4	2⅞	4	½	½	½	½	⅝	⅜	7/16	⅝
1	4¾	3 7/16	4	⅝	⅝	½	⅝	¾	⅜	½	11/16
1¼	5¼	3⅞	4	⅝	⅝	⅝	⅝	¾	½	½	11/16
1½	5½	4⅛	4	⅝	⅝	⅝	¾	⅞	½	9/16	¾
2	6½	5	4	⅝	¾	¾	⅞	1	⅝	11/16	⅞
2½	7¼	5¾	8	⅝	¾	¾	⅞	1	⅝	11/16	⅞
3	8	6½	8	⅝	¾	¾	1	1¼	⅝	¾	1
3½	8½	7	8	⅝	¾	⅞	1	1¼	¾	¾	1
4	9	7½	8	⅝	¾	⅞	1⅛	1⅜	¾	⅞	1⅛
4½	10	8¼	8	¾	⅞	⅞	1⅛	1⅜	¾	⅞	1⅛
5	11	9¼	8	¾	⅞	1	1¼	1½	⅞	1	1¼
6	12	10¼	12	¾	⅞	1	1¼	1½	⅞	1	1¼
7	13¼	11½	12	¾	⅞	1	1⅜	1⅝	⅞	1⅛	1⅜
8	14½	12¾	12	¾	⅞	1⅛	1⅜	1⅝	1	1⅛	1⅜
9	16	14	12	⅞	1	1⅛	1½	1¾	1	1¼	1½
10	17	15	12	⅞	1	1⅛	1½	1⅞	1	1¼	1⅝
11	18	16	16	⅞	1	1¼	1⅝	1⅞	1⅛	1⅜	1⅝
12	19¼	17¼	16	⅞	1	1¼	1⅝	2	1⅛	1⅜	1¾

The expansion for any length of pipe may be found by taking the difference in increased length at the minimum and maximum temperatures, dividing by 100 and multiplying by the length in feet of the line under consideration.

NATIONAL (AMERICAN) STANDARD FIRE HOSE COUPLING SCREW THREAD

Having Nominal Inside Diameters of 2½, 3, 3½, and 4½ Inches

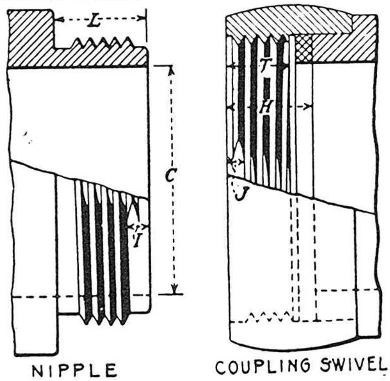


Fig. 1 Typical Form of Standard Coupling

Characteristics of the National Standard Fire-Hose Coupling Screw Thread

1	Nominal inside diameter of hose coupling (C)....	$2\frac{1}{2}$	3	$3\frac{1}{2}$	$4\frac{1}{2}$
2	Number of threads per inch....................	$7\frac{1}{2}$	6	6	4
3	Total length of threaded part of coupling and hydrant nipple, external thread (See L. Fig. 1).....	1	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$
4	Distance from face of nipple to start of second turn (See I, Fig. 1)...........................	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{7}{16}$
5	Depth of coupling swivel to washer seat (See H, Fig. 1)...................................	$\frac{15}{16}$	$1\frac{1}{16}$	$1\frac{1}{16}$	$1\frac{3}{16}$
6	Distance from face of coupling swivel to start of second turn (See J, Fig. 1)....................	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{8}$
7	Depth of thread of coupling swivel (See T, Fig. 1)	$\frac{11}{16}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{15}{16}$
8	Nipple (external thread) cylindrical to base of thread....................................	...	...	...	...
9	Coupling (internal thread) cylindrical to base of thread....................................	...	...	...	...
10	Outer ends of external and internal thread should be terminated by the "Higbee Cut" on *full thread* to avoid crossing and mutilation of thread.......	...	...	...	...
11	American (National) Form of thread must be used.	...	...	...	...

All dimensions given in inches.

Limiting Dimensions for Threads of Coupling Swivels and Hydrant Caps (Internal)

Nominal Size	No. of Threads Per Inch	Min. Major Diameter	Pitch Diameter		Mino Diameter	
			Max.	Min.	Max.	Min.
2.500	7.5	3.0836	3.0130	2.9970	2.9424	2.9104
3.000	6.0	3.6389	3.5486	3.5306	3.4583	3.4223
3.500	6.0	4.2639	4.1736	4.1556	4.0833	4.0473
4.500	4.0	5.7859	5.6485	5.6235	5.5111	5.4611

All dimensions given in inches.

Limiting Dimensions of Threads of Coupling and Hydrant Nipples (External)

Nominal Size	No. of Threads Per Inch	Major Diameter		Pitch Diameter		Max. Minor Diameter
		Max.	Min.	Max.	Min.	
2.500	7.5	3.0686	4.0366	2.9820	2.9660	2.8954
3.000	6.0	3.6239	3.5879	3.5156	3.4976	3.4073
3.500	6.0	4.2439	4.2079	4.1356	4.1176	4.0273
4.500	4.0	5.7609	5.7109	5.5985	5.5735	5.4361

All dimensions given in inches.

STANDARD MANUFACTURING TOLERANCES

ROUND WELDED STAINLESS STEEL TUBING

Diameter Tolerances

Dimensions of Tube		Ornamental Flash-In Tube			Full Finished Tube			O.D. Up to 25% Closer Std. I.D. No Spec.		O.D. Up to 25% Closer than Std. I.D. Up to 40% Closer than Std.		
Size of Tube, Inches	B.W. Gauge	O.D.	I.D. Flash	Ovality	O.D.	I.D.	Ovality	O.D.	Ovality	O.D.	I.D.	Ovality
3/8	16 to 23				±.003	±.009	.004	±.002	.003	±.002	±.0055	.003
1/2	16 to 23	±.004	3/64	.004	±.003	±.009	.004	±.002	.003	±.002	±.0055	.003
1/2	13 to 14				±.003	±.013	.004	±.002	.003			
5/8	16 to 22	±.005	3/64	.005	±.004	±.005	.004	±.003	.003	±.003	±.003	.003
5/8	13 to 14	.....	..	...	±.005	±.014	.006	±.004	.005	.....	.....	....
3/4 to 7/8	18 to 23	±.005	3/64	.008	±.004	±.005	.005	±.003	.005	±.003	±.003	.005
3/4 to 7/8	14 to 16	±.004	3/64	.006	±.004	±.005	.004	±.003	.004	±.003	±.003	.004
3/4 to 7/8	12 to 13	.....	..	...	±.005	±.006	.005	±.004	.005	±.004	±.0035	.005
1	18 to 23	±.005	3/64	.008	±.004	±.005	.005	±.003	.005	±.003	±.003	.005
1	13 to 16	±.004	3/64	.008	±.004	±.005	.004	±.003	.004	±.003	±.003	.004
1	11 to 12	.....	..	...	±.005	±.006	.005	±.004	.005	±.004	±.0035	.005
1 1/8 to 1 1/4	18 to 23	±.005	3/64	.008	±.005	±.005	.008	±.004	.006	±.004	±.003	.006
1 1/8 to 1 1/4	14 to 16	±.005	3/64	.006	±.005	±.0075	.005	±.004	.005	±.004	±.0045	.005
1 1/8 to 1 1/4	11 to 13	±.006	3/64	.007	±.006	±.006	.007	±.0045	.0055	±.0045	±.0035	.0055

(Continued)

STANDARD MANUFACTURING TOLERANCES

ROUND WELDED STAINLESS STEEL TUBING—(Cont'd)
Diameter Tolerances

Dimensions of Tube		Ornamental Flash-In Tube			Full Finished Tube			O.D. Up to 25% Closer Std. I.D. No Spec.		O.D. Up to 25% Closer than Std. I.D. Up to 40% Closer than Std.		
Size of Tube, Inches	B.W. Gauge	O.D.	I.D. Flash	Ovality	O.D.	I.D.	Ovality	O.D.	Ovality	O.D.	I.D.	Ovality
(Continued)												
$1\frac{3}{8}$	18 to 23	±.005	$\frac{3}{64}$	.008	±.005	±.006	.008	±.004	.006	±.004	±.0035	.006
$1\frac{3}{8}$	14 to 16	±.005	$\frac{3}{64}$	.006	±.005	±.0075	.006	±.004	.006	±.004	±.0045	.005
$1\frac{3}{8}$	10 to 13	±.006	$\frac{3}{64}$	.008	±.006	±.0085	.008	±.0045	.0055	±.0045	±.005	.0055
$1\frac{1}{2}$ to 2	18 to 23	±.006	$\frac{3}{64}$	.008	±.006	±.006	.008	±.0045	.006	±.0045	±.0035	.006
$1\frac{1}{2}$ to 2	14 to 16	±.005	$\frac{3}{64}$	.008	±.005	±.006	.006	±.004	.005	±.004	±.0035	.005
$1\frac{1}{2}$ to 2	10 to 13	.....	..	...	±.005	±.0075	.006	±.004	.005	±.004	±.0045	.005
$2\frac{1}{8}$ to $2\frac{1}{2}$	18 to 20				±.008	±.008	.010	±.006	.0075	±.006	±.005	.0075
$2\frac{1}{8}$ to $2\frac{1}{2}$	14 to 16	.....	..	...	±.008	±.008	.010	±.006	.007	±.006	±.005	.007
$2\frac{1}{8}$ to $2\frac{1}{2}$	10 to 13	.....	..	...	±.008	±.008	.010	±.006	.007	±.006	±.005	.007
$2\frac{5}{8}$ to 3	16 to 20				±.010	±.010	.020	±.0075	.010	±.006	±.005	.0075
$2\frac{5}{8}$ to 3	12 to 14	.....	..	...	±.010	±.010	.015	±.0075	.010	.....	.....	....
$2\frac{5}{8}$ to 3	10 to 11	.....	..	...	±.010	±.010	.015	±.0075	.008	.....	.....	....
$3\frac{1}{8}$ to $3\frac{1}{2}$	14 to 19				±.012	±.012	.020	±.010	.012			
$3\frac{1}{8}$ to $3\frac{1}{2}$	11 to 13	.....	..	...	±.010	±.012	.020	±.008	.010	.....	.....	....
$3\frac{5}{8}$ to 4	14 to 18	.....	..	...	±.016	±.016	.025	±.012	.012	.....	.....	....
$3\frac{5}{8}$ to 4	11 to 13				±.012	±.016	.025	±.008	.010			
$4\frac{1}{8}$ to 5	14 to 18	.....	..	...	±.022	.....	.032	.....	...	.....	.....	....
$4\frac{1}{8}$ to 5	11 to 13				±.016		.032					

SPECIAL STRAIGHT FIXTURE PIPE THREADS

EXTERNAL THREADS

SIZES—DIMENSIONS IN INCHES

Pipe Size Inches	Number of Threads to Inch	Major Diameter Max.	Major Diameter Min.	Pitch Diameter Max. (Basic)	Pitch Diameter Min.	Tolerance P. D.	Minor Diam. Max.	Min. Length of Thread
1/8	27	0.3989	0.3868	0.3748	0.3708	0.004	0.3507	0.2638
1/4	18	0.5260	0.5089	0.4899	0.4849	0.005	0.4538	0.4018
3/8	18	0.6631	0.6460	0.6270	0.6220	0.005	0.5909	0.4078
1/2	14	0.8248	0.8033	0.7784	0.7724	0.006	0.7320	0.5337
3/4	14	1.0353	1.0138	0.9889	0.9829	0.006	0.9425	0.5457
1	11½	1.2951	1.2692	1.2386	1.2316	0.007	1.1821	0.6828

SPECIAL STRAIGHT FIXTURE PIPE THREADS

INTERNAL THREADS

SIZES— DIMENSIONS IN INCHES

Pipe Size Inches	Number of Threads to Inch	Minor Diameter Min.	Minor Diameter Max.	Pitch Diameter Min. (Basic)	Pitch Diameter Max.	Tolerance P. D.	Major Diam. Min.	Min. Length of Thread
1/8	27	0.3507	0.3628	0.3748	0.3788	0.004	0.3989	0.2638
1/4	18	0.4538	0.4709	0.4899	0.4949	0.005	0.5260	0.4018
3/8	18	0.5909	0.6080	0.6270	0.6320	0.005	0.6631	0.4078
1/2	14	0.7320	0.7535	0.7784	0.7844	0.006	0.8248	0.5337
3/4	14	0.9425	0.9640	0.9889	0.9949	0.006	1.0353	0.5457
1	11½	1.1821	1.2080	1.2386	1.2456	0.007	1.2951	0.6828

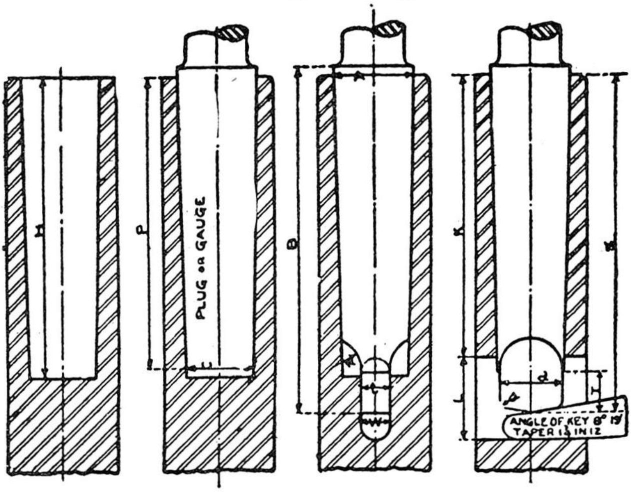
ALUMINUM PIPE SIZES

Seamless Drawn Aluminum Tubes made to correspond with Iron Tubes and to fit Iron Tube Fittings.

List of Sizes, Lengths, etc.

Same as Iron, Size	Outside Diameter	Inside Diameter	Weights per Foot: Aluminum lbs.	Brass lbs.	Copper lbs.
1/8	.405	.270	.083	.27	.29
1/4	.540	.364	.145	.37	.39
3/8	.675	.494	.193	.60	.64
1/2	.840	.623	.290	.76	.80
3/4	1.050	.824	.387	1.22	1.28
1	1.315	1.048	.577	1.63	1.74
1¼	1.660	1.380	.777	2.52	2.65
1½	1.900	1.611	.928	2.94	3.12
2	2.375	2.067	1.24	4.28	4.53
2½	2.875	2,468	1.98	5.58	5.92
3	3.500	3.067	2.59	8.35	8.84
3½	4.000	3.548	3.11	10.30	10.90
4	4.500	4.026	3.69	12.24	12.96

Brown & Sharpe Taper Shanks



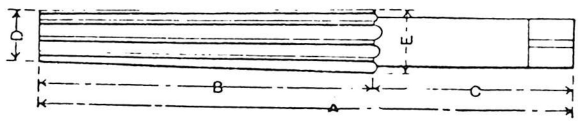
No. of Taper	Diam. of Plug at Small End	Diam. at End of Socket	Standard Plug Depth	Whole Length of Shank	Depth of Hole	End of Socket to Keyway	Length of Keyway	Width of Keyway	Length of Tongue	Diam. of Tongue	Thickness of Tongue	Radius of Mil for Tongue	Radius of Tongue	Shank Depth	Taper per Foot	Taper per Inch
	D	A	P	B	H	K	L	W	T	d	t	R	a	S		
4	.35	.402	1 1/4	1 3/4	1 3/8	1 13/64	11/16	.228	11/32	.320	7/32	5/16	.050	1 21/32	.500	.0416
5	.45	.5229	1 3/4	2 9/32	1 7/8	1 11/16	3/4	.260	3/8	.420	1/4	5/16	.060	2 3/16	.500	.0416
6	.50	.599	2 3/8	2 31/32	2 1/2	2 19/64	7/8	.291	7/16	.460	9/32	5/16	.060	2 7/8	.500	.0416
7	.60	.725	3	3 5/8	3 1/8	2 29/32	15/16	.322	15/32	.560	5/16	3/8	.070	3 17/32	.500	.0416
8	.75	.8985	3 9/16	4 1/4	3 11/16	3 29/32	1	.353	1/2	.710	11/32	3/8	.080	4 1/8	.500	.0416
9	.90	1.0667	4	4 3/4	4 1/8	3 7/8	1 1/8	.385	9/16	.860	3/8	7/16	.100	4 5/8	.500	.0416
10	1.0446	1.289	5 11/16	6 3/4	5 13/16	5 17/32	1 5/16	.447	21/32	1.01	7/16	1/2	.110	6 13/32	.5161	.043
11	1.25	1.53	6 3/4	7 13/16	6 7/8	6 19/32	1 5/16	.447	21/32	1.21	7/16	1/2	.130	7 15/32	.500	.0416
12	1.50	1.797	7 1/8	8 9/32	7 1/4	6 15/16	1 1/2	.510	3/4	1.46	1/2	1/2	.150	7 15/16	.500	.0416
13	1.75	2.0729	7 3/4	8 29/32	7 7/8	7 9/16	1 1/2	.510	3/4	1.710	1/2	5/8	.170	8 9/16	.500	.0416
14	2.00	2.3437	8 1/4	9 1/2	8 3/8	8 1/32	1 11/16	.572	27/32	1.960	9/16	3/4	.190	9 5/32	.500	.0416
15	2.25	2.6145	8 3/4	10	8 7/8	8 17/32	1 11/16	.572	27/32	2.210	9/16	7/8	.210	9 21/32	.500	.0416
16	2.50	2.8855	9 1/4	10 1/2	9 3/8	9	1 7/8	.635	15/16	2.450	5/8		.230	10 1/4	.500	.0416

Brown & Sharpe Standard Tapers

FOR SPINDLES, ARBORS, COLLETS, etc.

No. of Taper	Diam. at Small End, Inches	No. of Taper	Diam. at Small End, Inches	No. of Taper	Diam. at Small End, Inches
1	.200	7	.600	13	1.750
2	.250	8	.750	14	2.000
3	.312	9	.900	15	2.250
4	.350	10	1.0446	16	2.500
5	.450	11	1.250	17	2.750
6	.500	12	1.500	18	3.000

Standard Taper Pin Reamers*

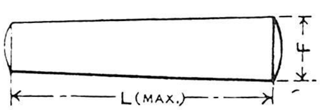


Taper, ¼ inch per foot.

No. of Taper Pin Reamer	Diameter at Large End of Reamer E	Diameter at Small End of Reamer D	Total Length of Reamer A	Length of Cutting Edges B	Length of Shank C	No. of Flutes
00000	0.0984	0.075	1-5/8	1-1/8	1/2	4
0000	0.1140	0.088	1-3/4	1-1/4	1/2	4
000	0.1296	0.101	2	1-3/8	5/8	4
00	0.1452	0.114	2-1/4	1-1/2	3/4	4
0	0.1608	0.127	2-3/8	1-5/8	3/4	6
1	0.1824	0.146	2-1/2	1-3/4	3/4	6
2	0.2036	0.162	3	2	1	6
3	0.2298	0.183	3-1/2	2-1/4	1-1/4	6
4	0.2600	0.208	4	2-1/2	1-1/2	6
5	0.3024	0.240	4-1/2	3	1-1/2	6
6	0.3544	0.279	5	3-5/8	1-1/2	6
7	0.4246	0.331	6	4-1/2	1-1/2	6
8	0.5072	0.398	6-3/4	5-1/4	1-1/2	8
9	0.6094	0.482	8	6-1/8	1-7/8	8
10	0.7266	0.581	9	7	2	8
11	0.8776	0.706	11-1/4	8-1/4	3	8
12	1.050	0.842	13-3/8	10	3-3/8	....
13	1.2586	1.009	16	12	4	....
14	1.5412	1.250	18-1/4	14	4-1/4	....

*Adopted by manufacturers of reamers and taper pins.

Standard Taper Pins



Taper, ¼ inch per foot

No. of Taper Pin	Diameter F at Large End of Pin	Approx. Fractional Size F	Maximum Length L
00000	0.094	3/32	3/4
0000	0.109	7/64	7/8
000	0.125	1/8	1
00	0.141	9/64	1-1/8
0	0.156	5/32	1-1/4
1	0.172	11/64	1-1/4
2	0.193	3/16	1-1/2
3	0.219	7/32	1-3/4
4	0.250	1/4	2
5	0.289	19/64	2-1/4
6	0.341	11/32	3
7	0.409	13/32	3-3/4
8	0.492	1/2	4-1/2
9	0.591	19/32	5-1/4
10	0.706	23/32	6
11	0.860	55/64	7-1/4
12	1.032	1-1/32	9
13	1.241	1-15/64	11
14	1.523	1-33/64	13

While filing and polishing try work in gauge and use rub test with Prussian Blue to insure proper taper and fit.

A cut of 8 thousandths will allow the gauge to go approximately ⅜″ farther on the work on either Jarno or Morse taper and approximately $\frac{5}{16}$″ on a Brown & Sharpe taper.

Rules for Figuring Tapers

Given	To Find	Rule
The taper per foot........	The taper per inch.........	Divide the taper per foot by 12.
The taper per inch........	The taper per foot.........	Multiply the taper per inch by 12.
End diameters and length of taper in inches.......	The taper per foot.........	Subtract small diameter from large; divide by length of taper, and multiply quotient by 12.
Large diameter and length of taper in inches and taper per foot..........	Diameter at small end in inches..................	Divide taper per foot by 12; multiply by length of taper, and subtract result from large diameter.
Small diameter and length of taper in inches, and taper per foot.........	Diameter at large end in inches..................	Divide taper per foot by 12; multiply by length of taper; and add result to small diameter.
The taper per foot and two diameters in inches.....	Distance between two given diameters in inches......	Subtract small diameter from large; divide remainder by taper per foot, and multiply quotient by 12.
The taper per foot........	Amount of taper in a certain length given in inches....	Divide taper per foot by 12; multiply by given length of tapered part.

TAPERS PER FOOT, AND CORRESPONDING ANGLES

Taper Per Foot	Included Angle			Angle With Center Line			Taper Per Foot	Included Angle			Angle With Center Line		
	Deg.	Min.	Sec.	Deg.	Min.	Sec.		Deg.	Min.	Sec.	Deg.	Min.	Sec.
1/64	0	4	28	0	2	14	1 7/8	8	56	2	4	28	1
1/32	0	8	58	0	4	29	1 15/16	9	13	50	4	36	55
1/16	0	17	54	0	8	57	2	9	31	36	4	45	48
3/32	0	26	52	0	13	26	2 1/8	10	7	10	5	3	35
1/8	0	35	48	0	17	54	2 1/4	10	42	42	5	21	21
5/32	0	44	44	0	22	22	2 3/8	11	18	10	5	39	5
3/16	0	53	44	0	26	52	2 1/2	11	53	36	5	56	48
7/32	1	2	34	0	31	17	2 5/8	12	29	2	6	14	31
1/4	1	11	36	0	35	48	2 3/4	13	4	24	6	32	12
9/32	1	20	30	0	40	15	2 7/8	13	39	42	6	49	51
5/16	1	29	30	0	44	45	3	14	15	0	7	7	30
11/32	1	38	22	0	49	11	3 1/8	14	50	14	7	25	7
3/8	1	47	24	0	53	42	3 1/4	15	25	24	7	42	42
13/32	1	50	24	0	58	12	3 3/8	16	0	34	8	0	17
7/16	2	5	18	1	2	39	3 1/2	16	35	40	8	17	50
15/32	2	14	16	1	7	8	3 5/8	17	10	40	8	35	20
1/2	2	23	10	1	11	35	3 3/4	17	45	40	8	52	50
17/32	2	32	4	1	16	2	3 7/8	18	20	34	9	10	17
9/16	2	41	4	1	20	32	4	18	55	28	9	27	44
19/32	2	50	2	1	25	1	4 1/8	19	30	18	9	45	9
5/8	2	59	42	1	29	51	4 1/4	20	5	2	10	2	31
21/32	3	7	56	1	33	58	4 3/8	20	39	44	10	19	52
11/16	3	16	54	1	38	27	4 1/2	21	14	2	10	37	1
23/32	3	25	50	1	42	55	4 5/8	21	48	54	19	54	27
3/4	3	34	44	1	47	22	4 3/4	22	23	22	11	11	41
25/32	3	43	44	1	51	52	4 7/8	22	57	48	11	28	54
13/16	3	52	38	1	56	19	5	23	32	12	11	46	6
27/32	4	1	36	2	0	48	5 1/8	24	6	28	12	3	14
7/8	4	10	32	2	5	16	5 1/4	24	40	42	12	20	21
29/32	4	19	34	2	9	47	5 3/8	25	14	48	12	37	24
15/16	4	28	24	2	14	12	5 1/2	25	48	48	12	54	24
31/32	4	37	20	2	18	40	5 5/8	26	22	52	13	11	26
1	4	46	18	2	23	9	5 3/4	26	56	46	13	28	23
1 1/16	5	4	12	2	32	6	5 7/8	27	30	34	13	45	17
1 1/8	5	21	44	2	40	52	6	28	4	2	14	2	1
1 3/16	5	39	54	2	49	57	6 1/8	28	37	58	14	18	59
1 1/4	5	57	48	2	58	54	6 1/4	29	11	34	14	35	47
1 5/16	6	15	38	3	7	49	6 3/8	29	45	18	14	52	39
1 3/8	6	33	26	3	16	43	6 1/2	30	18	26	15	9	13
1 7/16	6	51	20	3	25	40	6 5/8	30	51	48	15	25	54
1 1/2	7	9	10	3	34	35	6 3/4	31	25	2	15	42	31
1 9/16	7	26	58	3	43	29	6 7/8	31	58	10	15	59	5
1 5/8	7	44	48	3	52	24	7	32	31	12	15	15	36
1 11/16	8	2	38	4	1	19	7 1/8	33	4	8	16	32	4
1 3/4	8	20	26	4	10	13	7 1/4	33	36	40	16	48	20
1 13/16	8	38	16	4	19	8	7 3/8	34	9	50	16	4	55

GUIDE

This method cannot be used for boring tapers.

The amount the tailstock top must be set over depends on the amount of the taper per foot and the over-all length of the work. With the same amount of setover, pieces of different lengths will be machined with different tapers, as shown in Fig. 1 Notice that the tailstock center is set over one-half the total amount of the taper for the entire length of the work.

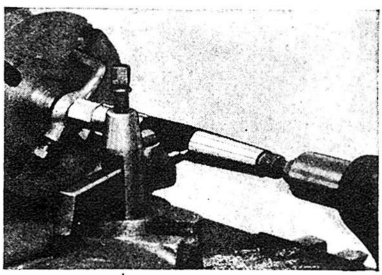


Fig. 1 Machining a Taper with the Tailstock Top Set Over

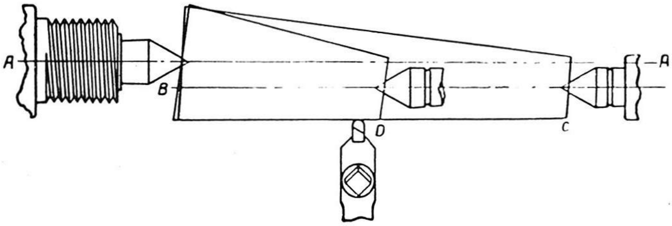
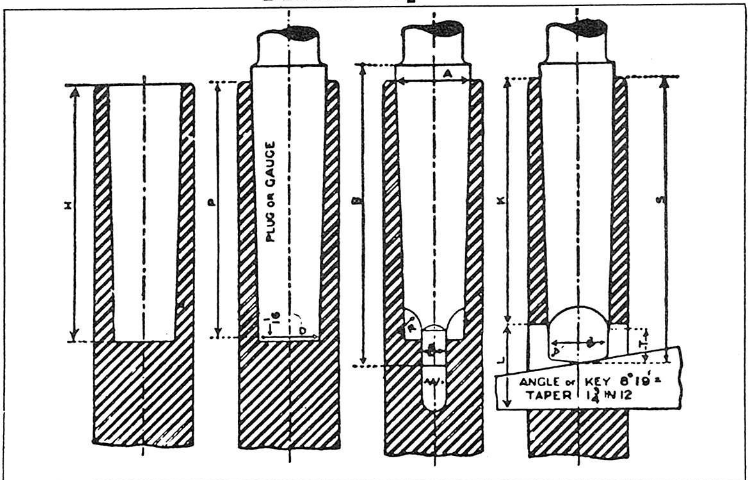


Fig. 2 With the Tailstock Set Over the Same Amount, Pieces of Different Lengths are Machined with Different Tapers

GUIDE

Morse Tapers



Number of Taper	Diam. of Plug at Small End, Inches	Diam. at End of Socket, Inches	SHANK: Whole Length of Shank, Inches	SHANK: Shank Depth, Inches	Depth of Hole, Inches	Standard Plug Depth, Inches	TONGUE: Thickness of Tongue, Inches	TONGUE: Length of Tongue, Inches	TONGUE: Rad. of Mill for Tongue, Inches	TONGUE: Diameter of Tongue, Inches	TONGUE: Radius of Tongue, Inches	KEYWAY: Width of Keyway, Inches	KEYWAY: Length of Keyway, Inches	KEYWAY: End of Socket to Keyway, Inches	Taper per Foot	Taper per Inch	Number of Key
	D	A	B	S	H	P	t	T	R	d	a	W	L	K			
0	.252	.3561	2 11/32	2 7/32	2 1/32	2	5/32	1/4	5/32	.235	.04	.160	9/16	1 15/16	.62460	.05205	0
1	.369	.475	2 9/16	2 7/16	2 3/16	2 1/8	13/64	3/8	3/16	.343	.05	.213	3/4	2 1/16	.59858	.04988	1
2	.572	.700	3 1/8	2 15/16	2 5/8	2 9/16	1/4	7/16	1/4	17/32	.06	.260	7/8	2 1/2	.59941	.04995	2
3	.778	.938	3 7/8	3 11/16	3 1/4	3 3/16	5/16	9/16	9/32	23/32	.08	.322	1 3/16	3 1/16	.60235	.05019	3
4	1.020	1.231	4 7/8	4 5/8	4 1/8	4 1/16	15/32	5/8	5/16	31/32	.10	.478	1 1/4	3 7/8	.62326	.05193	4
5	1.475	1.748	6 1/8	5 7/8	5 1/4	5 3/16	5/8	3/4	3/8	1 13/32	.12	.635	1 1/2	4 15/16	.63151	.05262	5
6	2.116	2.494	8 9/16	8 1/4	7 3/8	7 1/4	3/4	1 1/8	1/2	2	.15	.760	1 3/4	7	.62565	.05213	6
7	2.750	3.270	11 5/8	11 1/4	10 1/8	10	1 1/8	1 3/8	3/4	2 5/8	.18	1.135	2 5/8	9 1/2	.62400	.05200	7

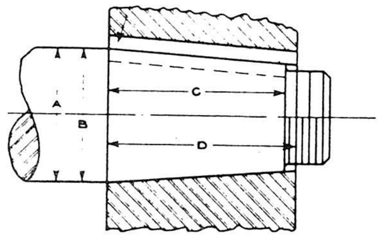
Brown & Sharpe Standard Taper Holes

FOR SPINDLES, COLLETS, ETC.

No of Taper	Approx. Diam. at Large End, Inches	No. of Taper	Approx. Diam. at Large End, Inches	No of Taper	Approx. Diam at Large End, Inches
6	19-32	10	1 1-4	14	2 11-32
7	23-32	11	1 1-2	16	2 7-8
9	1 1-16	12	1 13-16	18	3 7-16

COMPOUND FOR WELDING CAST STEEL. Mix 41 parts of boracic acid, 35 parts of pure, dried common salt, 20 parts of ferrocyanide of potassium, 8 parts rosin and 4 parts carbonate of sodium. When this compound is to be used, a sufficient quantity is scattered upon the article to be welded, which has been heated to a light red heat. It is then heated to a strong yellow heat and the welding accomplished in the usual manner.

S. A. E. TAPER DIMENSIONS

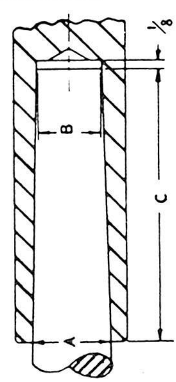


TAPER PER FOOT = 1.500 ± 0.005 IN.

Nominal Diameter Inches	A Diam. of Shaft		B Diam. of Hole		C Length Shaft	D Length Hole
	Max.	Min.	Max.	Min.		
1/4	0.250	0.249	0.248	0.247	5/16	3/8
3/8	0.375	0.374	0.373	0.372	7/16	1/2
1/2	0.500	0.499	0.498	0.497	11/16	3/4
5/8	0.625	0.624	0.623	0.622	11/16	3/4
3/4	0.750	0.749	0.748	0.747	15/16	1
7/8	0.875	0.874	0.873	0.872	1 1/8	1 1/4
1	1.001	0.999	0.997	0.995	1 3/8	1 1/2
1 1/8	1.126	1.124	1.122	1.120	1 3/8	1 1/2
1 1/4	1.251	1.249	1.247	1.245	1 3/8	1 1/2
1 3/8	1.376	1.374	1.372	1.370	1 7/8	2
1 1/2	1.501	1.499	1.497	1.495	1 7/8	2
1 5/8	1.626	1.624	1.622	1.620	2 1/8	2 1/4
1 3/4	1.751	1.749	1.747	1.745	2 1/8	2 1/4
1 7/8	1.876	1.874	1.872	1.870	2 3/8	2 1/2
2	2.001	1.999	1.997	1.995	2 7/8	3
2 1/4	2.252	2.248	2.245	2.242	2 7/8	3
2 1/2	2.502	2.498	2.495	2.492	3 3/8	3 1/2
2 3/4	2.752	2.748	2.745	2.742	3 3/8	3 1/2
3	3.002	2.998	2.995	2.992	3 7/8	4
3 1/4	3.252	3.248	3.245	3.242	4 1/8	4 1/4
3 1/2	3.502	3.498	3.495	3.492	4 3/8	4 1/2
4	4.002	3.998	3.995	3.992	5 3/8	5 1/2

Jarno Taper Shanks

Number of Taper	Diameter at End of Socket Inches A	Diameter of Plug at Small End Inches B	Standard Plug Depth Inches C
1	0.125	0.10	1/2
2	0.250	0.20	1
3	0.375	0.30	1 1/2
4	0.500	0.40	2
5	0.625	0.50	2 1/2
6	0.750	0.60	3
7	0.875	0.70	3 1/2
8	1.000	0.80	4
9	1.125	0.90	4 1/2
10	1.250	1.00	5
11	1.375	1.10	5 1/2
12	1.500	1.20	6
13	1.625	1.30	6 1/2
14	1.750	1.40	7
15	1.875	1.50	7 1/2
16	2.000	1.60	8
17	2.125	1.70	8 1/2
18	2.250	1.80	9
19	2.375	1.90	9 1/2
20	2.500	2.00	10

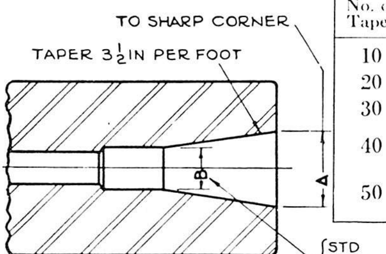


TAPERS FROM 1-16 TO 1 1-4 INCH PER FOOT
AMOUNT OF TAPER FOR LENGTHS UP TO 24 INCHES

Length Tapered Inches	TAPER PER FOOT									
	1-16	3-32	1-8	1-4	3-8	1-2	5-8	3-4	1	1 1-4
1-32	.0002	.0002	.0003	.0007	.0010	.0013	.0016	.0020	.0026	.0033
1-16	.0003	.0005	.0007	.0013	.0020	.0026	.0033	.0039	.0052	.0065
1-8	.0007	.0010	.0013	.0026	.0039	.0052	.0065	.0078	.0104	.0130
3-16	.0010	.0015	.0020	.0039	.0059	.0078	.0098	.0117	.0156	.0195
1-4	.0013	.0020	.0026	.0052	.0078	.0104	.0130	.0156	.0208	.0260
5-16	.0016	.0024	.0033	.0065	.0098	.0130	.0163	.0195	.0260	.0326
3-8	.0020	.0029	.0039	.0078	.0117	.0156	.0195	.0234	.0312	.0391
7-16	.0023	.0034	.0046	.0091	.0137	.0182	.0228	.0273	.0365	.0456
1-2	.0026	.0039	.0052	.0104	.0156	.0208	.0260	.0312	.0417	.0521
9-16	.0029	.0044	.0059	.0117	.0176	.0234	.0293	.0352	.0469	.0586
5-8	.0033	.0049	.0065	.0130	.0195	.0260	.0326	.0391	.0521	.0651
11-16	.0036	.0054	.0072	.0143	.0215	.0286	.0358	.0430	.0573	.0716
3-4	.0039	.0059	.0078	.0156	.0234	.0312	.0391	.0469	.0625	.0781
13-16	.0042	.0063	.0085	.0169	.0254	.0339	.0423	.0508	.0677	.0846
7-8	.0046	.0068	.0091	.0182	.0273	.0365	.0456	.0547	.0729	.0911
15-16	.0049	.0073	.0098	.0195	.0293	.0391	.0488	.0586	.0781	.0977
1	.0052	.0078	.0104	.0208	.0312	.0417	.0521	.0625	.0833	.1042
2	.0104	.0156	.0208	.0417	.0625	.0833	.1042	.125	.1667	.2083
3	.0156	.0234	.0312	.0625	.0937	.1250	.1562	.1875	.250	.3125
4	.0208	.0312	.0417	.0833	.125	.1667	.2083	.250	.3333	.4167
5	.0260	.0391	.0521	.1042	.1562	.2083	.2604	.3125	.4167	.5208
6	.0312	.0469	.0625	.125	.1875	.250	.3125	.375	.500	.625
7	.0365	.0547	.0729	.1458	.2187	.2917	.3646	.4375	.5833	.7292
8	.0417	.0625	.0833	.1667	.250	.3333	.4167	.500	.6667	.8333
9	.0469	.0703	.0937	.1875	.2812	.375	.4687	.5625	.750	.9375
10	.0521	.0781	.1042	.2083	.3125	.4167	.5208	.625	.8333	1.0417
11	.0573	.0859	.1146	.2292	.3437	.4583	.5729	.6875	.9167	1.1458
12	.0625	.0937	.125	.250	.375	.500	.625	.750	1.000	1.250
13	.0677	.1016	.1354	.2708	.4062	.5417	.6771	.8125	1.0833	1.3542
14	.0729	.1094	.1458	.2917	.4375	.5833	.7292	.875	1.1667	1.4583
15	.0781	.1172	.1562	.3125	.4687	.625	.7812	.9375	1.250	1.5625
16	.0833	.125	.1667	.3333	.500	.6667	.8333	1.000	1.3333	1.6667
17	.0885	.1328	.1771	.3542	.5312	.7083	.8854	1.0625	1.4167	1.7708
18	.0937	.1406	.1875	.3750	.5625	.750	.9375	1.125	1.500	1.875
19	.0990	.1484	.1979	.3958	.5937	.7917	.9896	1.1875	1.5833	1.9792
20	.1042	.1562	.2083	.4167	.625	.8333	1.0417	1.250	1.6667	2.0833
21	.1094	.1641	.2187	.4375	.6562	.875	1.0937	1.3125	1.750	2.1875
22	.1146	.1719	.2292	.4583	.6875	.9167	1.1458	1.375	1.8333	2.2917
23	.1198	.1797	.2396	.4792	.7187	.9583	1.1970	1.4375	1.9167	2.3958
24	.125	.1875	.250	.500	.750	1.000	1.250	1.500	2.000	2.500

Milling Machine Standard Tapers

as adopted by the Milling Machine Manufacturers of the National Machine Tool Builders' Association



No. of Taper	A	B	*Threaded End of Draw-In Bolt
10	5-8	3-8	
20	7-8	1-2	
30	1 1-4	5-8	
40	1 3-4	1	1-2" 13 N.C., R.H. 5-8" 11 N.C., R.H.
50	2 3-4	1 9-16	5-8" 11 N.C., R.H. 1" 8 N.C., R.H.

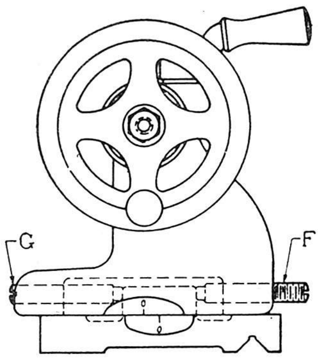
*End of Draw-In Bolt is threaded with two sizes of thread. The larger size thread is used in threaded hole in Arbors and in Adapters where possible, but limitations on certain Adapters require the use of a threaded hole to fit the smaller Threaded End of the Draw-In Bolt.

How to Calculate Amount of Setover for Tailstock

Tapers are usually specified in "inches per foot." For example some Brown & Sharpe tapers are ½ in. per foot. To machine a Brown & Sharpe taper of ½ in. per foot on a shaft exactly one foot long, the center should be set over ¼ in. or .250 in. If the piece is only 10 in. long, then the amount of setover would be $\frac{10}{12}$ of .250 in. or .208 in. The following rules may be used for calculating the amount of setover:

Taper in Inches per Foot Given—Divide the total length of the stock in inches by twelve and multiply this quotient by one-half the amount of taper per foot specified. The result is the amount of setover in inches.

Diameters at Ends of Taper Given—Divide the total length of the stock by the length of the portion to be tapered and multiply this quotient by one-half the difference in diameters; the result is the amount of the setover.

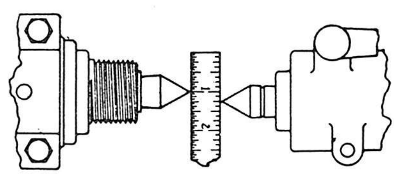


Adjusting the Tailstock Center

To set over the tailstock center for taper turning, loosen clamping nut of tailstock and back off set screw "G," illustrated the distance required; then screw in set screw "F" a like distance until it is tight, and clamp the tailstock to the lathe bed.

Measuring the Setover

To measure the setover of the tailstock center, place a scale having graduations on both edges between the two centers, as shown. This will give an approximate measurement.

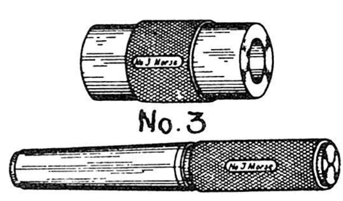


Measuring the Setover

Fitting Tapers to Gauges

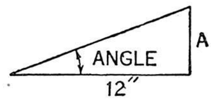
The best way to machine an accurate taper is to fit the taper to a standard gauge. To test the taper, make a chalk mark along the entire length of the taper, place the work in the taper it is to fit and turn carefully by hand. Then remove the work and the chalk mark will show where the taper is bearing.

If the taper is a perfect fit, it will show along the entire length of the chalk mark. If the taper is not perfect, make the necessary adjustment, take another light chip and test again. Be sure the taper is correct before turning to the finished diameter.



Morse Standard Taper Plug Gauge and Socket Gauge

Table of Bevels



A Height, Inches	0" Angle Deg.	0" Angle Min.	1" Angle Deg.	1" Angle Min.	2" Angle Deg.	2" Angle Min.	3" Angle Deg.	3" Angle Min.	4" Angle Deg.	4" Angle Min.	5" Angle Deg.	5" Angle Min.	6" Angle Deg.	6" Angle Min.	7" Angle Deg.	7" Angle Min.	8" Angle Deg.	8" Angle Min.	9" Angle Deg.	9" Angle Min.	10" Angle Deg.	10" Angle Min.	11" Angle Deg.	11" Angle Min.
0	....	....	4	45	9	28	14	03	18	26	22	37	26	34	30	15	33	42	36	52	39	48	42	31
1/32	0	09	4	55	9	37	14	11	18	35	22	45	26	41	30	22	33	48	36	58	39	54	42	36
1/16	0	18	5	04	9	45	14	19	18	43	22	53	26	49	30	29	33	54	37	04	39	59	42	40
3/32	0	27	5	12	9	54	14	28	18	50	23	00	26	55	30	35	34	00	37	10	40	05	42	45
1/8	0	36	5	20	10	02	14	36	18	59	23	08	27	02	30	42	34	07	37	15	40	10	42	50
5/32	0	45	5	31	10	12	14	45	19	07	23	15	27	10	30	49	34	13	37	20	40	15	42	55
3/16	0	54	5	39	10	20	14	53	19	15	23	23	27	17	30	56	34	18	37	26	40	20	43	00
7/32	1	02	5	48	10	29	15	01	19	23	23	30	27	24	31	02	34	24	37	32	40	25	43	05
1/4	1	11	5	57	10	38	15	09	19	30	23	38	27	30	31	09	34	30	37	38	40	30	43	10
9/32	1	20	6	06	10	46	15	18	19	38	23	46	27	38	31	15	34	37	37	43	40	35	43	14
5/16	1	30	6	15	10	55	15	26	19	46	23	53	27	45	31	22	34	43	37	49	40	40	43	19
11/32	1	38	6	24	11	04	15	34	19	54	24	00	27	52	31	28	34	49	37	55	40	46	43	24
3/8	1	47	6	32	11	12	15	42	20	02	24	08	27	58	31	35	34	55	38	00	40	51	43	28
13/32	1	57	6	41	11	20	15	51	20	10	24	16	28	06	31	41	35	00	38	05	40	56	43	33
7/16	2	06	6	50	11	29	16	00	20	18	24	23	28	13	31	48	35	07	38	11	41	01	43	38
15/32	2	15	6	59	11	38	16	08	20	26	24	30	28	20	31	54	35	13	38	16	41	06	43	42
1/2	2	24	7	08	11	46	16	16	20	34	24	38	28	27	32	00	35	19	38	22	41	11	43	47
17/32	2	33	7	16	11	55	16	24	20	41	24	45	28	34	32	07	35	25	38	27	41	16	43	51
9/16	2	41	7	25	12	03	16	32	20	49	24	53	28	41	32	14	35	31	38	33	41	21	43	56
19/32	2	50	7	34	12	12	16	40	20	57	25	00	28	48	32	20	35	36	38	39	41	26	44	01
5/8	2	59	7	43	12	20	16	49	21	05	25	08	28	55	32	26	35	42	38	44	41	31	44	06
21/32	3	08	7	52	12	30	16	57	21	12	25	15	29	02	32	32	35	48	38	50	41	37	44	10
11/16	3	17	8	00	12	38	17	05	21	20	25	22	29	08	32	38	35	55	38	55	41	41	44	15
23/32	3	26	8	09	12	46	17	13	21	28	25	29	29	15	32	45	36	00	39	00	41	46	44	20
3/4	3	35	8	18	12	55	17	21	21	35	25	37	29	22	32	51	36	06	39	06	41	51	44	24
25/32	3	44	8	27	13	04	17	30	21	44	25	44	29	28	32	58	36	12	39	11	41	56	44	29
13/16	3	52	8	35	13	12	17	38	21	52	25	51	29	35	33	04	36	17	39	16	42	01	44	33
27/32	4	01	8	44	13	20	17	46	21	59	25	58	29	42	33	10	36	24	39	21	42	06	44	38
7/8	4	10	8	53	13	29	17	54	22	07	26	05	29	48	33	17	36	30	39	27	42	11	44	42
29/32	4	20	9	02	13	37	18	02	22	15	26	13	29	55	33	23	36	35	39	32	42	16	44	47
15/16	4	28	9	11	13	45	18	10	22	22	26	20	30	02	33	29	36	40	39	38	42	21	44	51
31/32	4	37	9	20	13	54	18	18	22	30	26	27	30	09	33	35	36	46	39	43	42	26	44	56

Metric Threads

Metric threads can be cut through the quick change gear box by the addition of compound gears between the drive gear on the head and the gear on the feed box.

Size Lathe	Compound Gears	Range of Threads
10"	127T— 90T	1/4 M. M. Pitch to 3 3/4 M. M. Pitch
13"—15"	127T—120T	1/8 M. M. Pitch to 7 M. M. Pitch
17"—19"	127T—120T	3/16 M. M. Pitch to 16 M. M. Pitch
21"—24"	127T—120T	203 M. M. Pitch to 24 M. M. Pitch

Lengths of Circular Arcs

Degrees and Radius of Circle Being Given.

Formula:—Length of Arcs = $\frac{3.1416}{180}$ × Radius × number of degrees.

Rule:—Multiply the factor in the table for any given number of degrees by the radius.

Example:—Given, a curve of a radius of 55 ft. and an angle of 78° 20′, what is the length of the Arc?

Factor in the table for 78° = 1.361356
Factor in the table for 20′ = .005817

Factor = 1.367173

1.367173 × 55 ft. = 75.19 ft.

Degrees												Min.			
1	.017453	31	.541052	61	1.064650	91	1.588249	121	2.111848	151	2.635447	1	.000290	31	.009017
2	.034906	32	.558505	62	1.082104	92	1.605702	122	2.129301	152	2.652900	2	.000581	32	.009308
3	.052359	33	.575958	63	1.099557	93	1.623156	123	2.146755	153	2.670353	3	.000872	33	.009599
4	.069813	34	.593411	64	1.117010	94	1.640609	124	2.164208	154	2.687807	4	.001163	34	.009890
5	.087266	35	.610865	65	1.134464	95	1.658062	125	2.181661	155	2.705260	5	.001454	35	.010181
6	.104719	36	.628318	66	1.151917	96	1.675516	126	2.199114	156	2.722713	6	.001745	36	.010472
7	.122173	37	.645771	67	1.169370	97	1.692969	127	2.216568	157	2.740166	7	.002036	37	.010762
8	.139626	38	.663225	68	1.186823	98	1.710422	128	2.234021	158	2.757620	8	.002327	38	.011053
9	.157079	39	.680678	69	1.204277	99	1.727876	129	2.251474	159	2.775073	9	.002618	39	.011344
10	.174532	40	.698131	70	1.221730	100	1.745329	130	2.268928	160	2.792526	10	.002908	40	.011635
11	.191986	41	.715585	71	1.239183	101	1.762782	131	2.286381	161	2.809980	11	.003199	41	.011926
12	.209439	42	.733038	72	1.256637	102	1.780235	132	2.303834	162	2.827433	12	.003490	42	.012217
13	.226892	43	.750491	73	1.274090	103	1.797689	133	2.321287	163	2.844886	13	.003781	43	.012508
14	.244346	44	.767944	74	1.291543	104	1.815142	134	2.338741	164	2.862340	14	.004072	44	.012799
15	.261799	45	.785398	75	1.308996	105	1.832595	135	2.356194	165	2.879793	15	.004363	45	.013090
16	.279252	46	.802851	76	1.326450	106	1.850049	136	2.373647	166	2.897246	16	.004654	46	.013380
17	.296706	47	.820304	77	1.343903	107	1.867502	137	2.391101	167	2.914699	17	.004945	47	.013671
18	.314159	48	.837758	78	1.361356	108	1.884955	138	2.408554	168	2.932153	18	.005236	48	.013962
19	.331612	49	.855211	79	1.378810	109	1.902408	139	2.426007	169	2.949606	19	.005526	49	.014253
20	.349065	50	.872664	80	1.396263	110	1.919862	140	2.443461	170	2.967059	20	.005817	50	.014544
21	.366519	51	.890117	81	1.413716	111	1.937315	141	2.460914	171	2.984513	21	.006108	51	.014835
22	.383972	52	.907571	82	1.431170	112	1.954768	142	2.478367	172	3.001966	22	.006399	52	.015126
23	.401425	53	.925024	83	1.448623	113	1.972222	143	2.495820	173	3.019419	23	.006690	53	.015417
24	.418879	54	.942477	84	1.466076	114	1.989675	144	2.513274	174	3.036872	24	.006981	54	.015708
25	.436332	55	.959931	85	1.483529	115	2.007128	145	2.530727	175	3.054326	25	.007272	55	.015998
26	.453785	56	.977384	86	1.500983	116	2.024581	146	2.548180	176	3.071779	26	.007563	56	.016289
27	.471238	57	.994837	87	1.518436	117	2.042035	147	2.565634	177	3.089232	27	.007854	57	.016580
28	.488692	58	1.012291	88	1.535889	118	2.059488	148	2.583087	178	3.106686	28	.008144	58	.016871
29	.506145	59	1.029744	89	1.553343	119	2.076941	149	2.600540	179	3.124139	29	.008435	59	.017162
30	.523598	60	1.047197	90	1.570796	120	2.094395	150	2.617993	180	3.141592	30	.008726	60	.017453

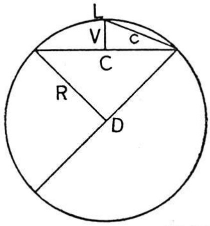
Decimals of a Foot for Each 1/32 of an Inch

Inches	0	1	2	3	4	5	6	7	8	9	10	11
0	0.0	0.0833	0.1667	0.2500	0.3333	0.4167	0.5000	0.5833	0.6667	0.7500	0.8333	0.9167
1/32	.0026	.0859	.1693	.2526	.3359	.4193	.5026	.5859	.6693	.7526	.8359	.9193
1/16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
3/32	.0078	.0911	.1745	.2578	.3411	.4245	.5078	.5911	.6745	.7578	.8411	.9245
1/8	.0104	.0937	.1771	.2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271
5/32	.0130	.0964	.1797	.2630	.3464	.4297	.5130	.5964	.6797	.7630	.8464	.9297
3/16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
7/32	.0182	.1016	.1849	.2682	.3516	.4349	.5182	.6016	.6849	.7682	.8516	.9349
1/4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
9/32	.0234	.1068	.1901	.2734	.3568	.4401	.5234	.6068	.6901	.7734	.8568	.9401
5/16	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
11/32	.0286	.1120	.1953	.2786	.3620	.4453	.5286	.6120	.6953	.7786	.8620	.9453
3/8	.0312	.1146	.1979	.2812	.3646	.4479	.5312	.6146	.6979	.7812	.8646	.9479
13/32	.0339	.1172	.2005	.2839	.3672	.4505	.5339	.6172	.7005	.7839	.8672	.9505
7/16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
15/32	.0391	.1224	.2057	.2891	.3724	.4557	.5391	.6224	.7057	.7891	.8724	.9557
1/2	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
17/32	.0443	.1276	.2109	.2943	.3776	.4609	.5443	.6276	.7109	.7943	.8776	.9609
9/16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
19/32	.0495	.1328	.2161	.2995	.3828	.4661	.5495	.6328	.7161	.7995	.8828	.9661
5/8	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
21/32	.0547	.1380	.2214	.3047	.3880	.4714	.5547	.6380	.7214	.8047	.8880	.9714
11/16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
23/32	.0599	.1432	.2266	.3099	.3932	.4766	.5599	.6432	.7266	.8099	.8932	.9766
3/4	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792
25/32	.0651	.1484	.2318	.3151	.3984	.4818	.5651	.6484	.7318	.8151	.8984	.9818
13/16	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
27/32	.0703	.1536	.2370	.3203	.4036	.4870	.5703	.6536	.7370	.8203	.9036	.9870
7/8	.0729	.1562	.2396	.3229	.4062	.4896	.5729	.6562	.7396	.8229	.9062	.9896
29/32	.0755	.1589	.2422	.3255	.4089	.4922	.5755	.6589	.7422	.8255	.9089	.9922
15/16	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948
31/32	.0807	.1641	.2474	.3307	.4141	.4974	.5807	.6641	.7474	.8307	.9141	.9974
1	....	....	....	....	....	....	....	....	....	....	....	1.0000

Areas and Volumes Plane Surfaces

CIRCLES

Let R = radius, D = diameter, L = length of arc, V = Rise, or height of arc, C = chord of the arc, c = chord of ½ the arc



500-517

Fig. 500-517.

$$L = \frac{8c - C}{3} \text{ very nearly}$$

$$C = 2\sqrt{c^2 - V^2} = 2\sqrt{(D-V) \times V}$$

$$c = \sqrt{D \times V} = \frac{3L + C}{8}$$

$$D = \frac{c^2}{V} = \frac{C^2}{4V} + V \qquad V = \frac{c^2}{D}$$

Area of a circle $= \pi R^2 = 3.1416 R^2$

Area of sector of circle = Arc of sector $\times$ ½ radius = ½ L R

SPHERES: Area of Sphere = 4 $\times$ Area of a great circle = πD^2

Volume of Sphere = Area $\times$ one third radius = $\frac{\pi D^3}{6}$

ELLIPSE: Area = ¼ π AB, A and B being length and breadth respectively.

TRIANGLES: Area = ½ Base $\times$ altitude

$= \sqrt{S(S-A)(S-B)(S-C)}$ S = ½ Sum of 3 sides, A, B and C.

TRAPEZIUM: Area = Sum of area of its 2 triangles.

TRAPEZOID: Area = ½ sum of parallel sides $\times$ perpendicular height.

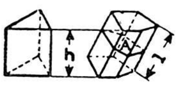
PARALLELOGRAM: Area = Base $\times$ perpendicular height.

REGULAR POLYGON: Area = ½ Sum of Sides $\times$ Inside radius.

Lateral Surfaces (S) and Volumes (V) of Miscellaneous Solids

Parallelopiped.

S = [perimeter, P, perpendicular to sides $\times$ lateral length, l] = Pl
V = [area of base, B, $\times$ perpendicular height, h] = Bh
V = [area of section, A, perpendicular to sides $\times$ lateral length, l] = Al

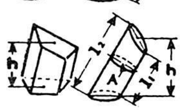


Prism, Right or Oblique, Regular or Irregular.

S = [perimeter, P, perpendicular to sides $\times$ latera length, l] = Pl
V = [area of base, B, $\times$ perpendicular height, h] = l Bh
V = [area of section, A, perpendicular to sides $\times$ lateral length, l] = Al

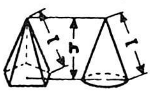
Cylinder, Right or Oblique, Circular or Elliptical.

S = [perimeter of base, P, $\times$ perpendicular height, h] = Ph
S = [perimeter, P_1, perpendicular to sides $\times$ lateral length, l] = $P_1 l$
V = [area of base, B, $\times$ perpendicular height, h] = Bh
V = [area of section, A, perpendicular to sides $\times$ lateral length, l] = Al



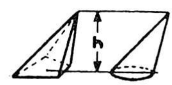
Frustum of Any Prism or Cylinder.

V = [area of base, B, $\times$ perpendicular distance, h, from base to center of gravity of opposite face] = Bh
For cylinder: V = ½A $(l_1 + l_2)$



Pyramid or Cone, Right and Regular

S = [perimeter of base, P, $\times$ ½ slant height, l] = ½ Pl
V = [area of base, B, $\times$ ⅓ perpendicular height, h] = ⅓ Bh

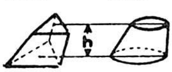


Pyramid or Cone, Right or Oblique, Regular or Irreg.

V = [area of base, B, $\times$ ⅓ perpendicular height, h] = ⅓ Bh
V = [⅓ volume of prism or cylinder of same base and perpendicular height]

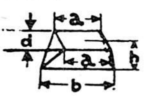
Frustum of Pyramid or Cone, Right and Regular, Parallel Ends.

S = [(sum of perimeter of base, P, and top, p) $\times$ ½ slant height, l] = ½l (P + p)
V = [(sum of areas of base, B, and top, b, + square root of their products) $\times$ ⅓ perpendicular height, h]
= ⅓h $(B + b + \sqrt{Bb})$



Frustum of Any Pyramid or Cone, Parallel Ends.

V = [(sum of areas of base, B, and top, b, + square root of their products) $\times$ ⅓ perpendicular height, h]
= ⅓h $(B + b + \sqrt{Bb})$



Wedge, Parallelogram Face

V = [⅙ (sum of three edges, a b a, $\times$ perpendicular height, h, $\times$ perpendicular width, d)] = ⅙ d h (2a + b)

("Kent" and "Carnegie")

TABLE FOR CONVERTING MINUTES INTO DECIMALS OF A DEGREE

Min.	Dec. of Degree	Min.	Dec. of Degree	Min.	Dec. of Degree	Min.	Dec. of Degree	Min.	Dec. of Degree
¼	0.00416	12¼	0.20416	24¼	0.40416	36¼	0.60416	48¼	0.80416
½	0.00833	12½	0.20833	24½	0.40833	36½	0.60833	48½	0.80833
¾	0.01250	12¾	0.21250	24¾	0.41250	36¾	0.61250	48¾	0.81250
1	0.01666	13	0.21666	25	0.41666	37	0.61666	49	0.81666
1¼	0.02083	13¼	0.22083	25¼	0.42083	37¼	0.62083	49¼	0.82083
1½	0.02500	13½	0.22500	25½	0.42500	37½	0.62500	49½	0.82500
1¾	0.02916	13¾	0.22916	25¾	0.42916	37¾	0.62916	49¾	0.82916
2	0.03333	14	0.23333	26	0.43333	38	0.63333	50	0.83333
2¼	0.03750	14¼	0.23750	26¼	0.43750	38¼	0.63750	50¼	0.83750
2½	0.04166	14½	0.24166	26½	0.44166	38½	0.64166	50½	0.84166
2¾	0.04583	14¾	0.24583	26¾	0.44583	38¾	0.64583	50¾	0.84583
3	0.05000	15	0.25000	27	0.45000	39	0.65000	51	0.85000
3¼	0.05416	15¼	0.25416	27¼	0.45416	39¼	0.65416	51¼	0.85416
3½	0.05833	15½	0.25833	27½	0.45833	39½	0.65833	51½	0.85833
3¾	0.06250	15¾	0.26250	27¾	0.46250	39¾	0.66250	51¾	0.86250
4	0.06666	16	0.26666	28	0.46666	40	0.66666	52	0.86666
4¼	0.07083	16¼	0.27083	28¼	0.47083	40¼	0.67083	52¼	0.87083
4½	0.07500	16½	0.27500	28½	0.47500	40½	0.67500	52½	0.87500
4¾	0.07916	16¾	0.27916	28¾	0.47916	40¾	0.67916	52¾	0.87916
5	0.08333	17	0.28333	29	0.48333	41	0.68333	53	0.88333
5¼	0.08750	17¼	0.28750	29¼	0.48750	41¼	0.68750	53¼	0.88750
5½	0.09166	17½	0.29166	29½	0.49166	41½	0.69166	53½	0.89166
5¾	0.09583	17¾	0.29583	29¾	0.49583	41¾	0.69583	53¾	0.89583
6	0.10000	18	0.30000	30	0.50000	42	0.70000	54	0.90000
6¼	0.10416	18¼	0.30416	30¼	0.50416	42¼	0.70416	54¼	0.90416
6½	0.10833	18½	0.30833	30½	0.50833	42½	0.70833	54½	0.90833
6¾	0.11250	18¾	0.31250	30¾	0.51250	42¾	0.71250	54¾	0.91250
7	0.11666	19	0.31666	31	0.51666	43	0.71666	55	0.91666
7¼	0.12083	19¼	0.32083	31¼	0.52083	43¼	0.72083	55¼	0.92083
7½	0.12500	19½	0.32500	31½	0.52500	43½	0.72500	55½	0.92500
7¾	0.12916	19¾	0.32916	31¾	0.52916	43¾	0.72916	55¾	0.92916
8	0.13333	20	0.33333	32	0.53333	44	0.73333	56	0.93333
8¼	0.13750	20¼	0.33750	32¼	0.53750	44¼	0.73750	56¼	0.93750
8½	0.14166	20½	0.34166	32½	0.54166	44½	0.74166	56½	0.94166
8¾	0.14583	20¾	0.34583	32¾	0.54583	44¾	0.74583	56¾	0.94583
9	0.15000	21	0.35000	33	0.55000	45	0.75000	57	0.95000
9¼	0.15416	21¼	0.35416	33¼	0.55416	45¼	0.75416	57¼	0.95416
9½	0.15833	21½	0.35833	33½	0.55833	45½	0.75833	57½	0.95833
9¾	0.16250	21¾	0.36250	33¾	0.56250	45¾	0.76250	57¾	0.96250
10	0.16666	22	0.36666	34	0.56666	46	0.76666	58	0.96666
10¼	0.17083	22¼	0.37083	34¼	0.57083	46¼	0.77083	58¼	0.97083
10½	0.17500	22½	0.37500	34½	0.57500	46½	0.77500	58½	0.97500
10¾	0.17916	22¾	0.37916	34¾	0.57916	46¾	0.77916	58¾	0.97916
11	0.18333	23	0.38333	35	0.58333	47	0.78333	59	0.98333
11¼	0.18750	23¼	0.38750	35¼	0.58750	47¼	0.78750	59¼	0.98750
11½	0.19166	23½	0.39166	35½	0.59166	47½	0.79166	59½	0.99166
11¾	0.19583	23¾	0.39583	35¾	0.59583	47¾	0.79583	59¾	0.99583
12	0.20000	24	0.40000	36	0.60000	48	0.80000	60	1.00000

RECIPROCALS OF COMMON UNITS

Unit Number Reciprocal

Unit	Number	Reciprocal
Dozen	12	.0833333
Gross	144	.0069445
Square Foot	144	.0069445
Cubic Foot	1728	.0005787
Mile	5280	.00018939
Ton	2000	.0005000
Long Ton	2240	.0004643
Ream	480	.0020833
Ream	500	.0020000
Year (days)	360	.0027778
Year (days)	365	.0027397
Months (days)	28	.0357140
Months (days)	29	.0344830
Months (days)	30	.0333330
Months (days)	31	.0322580

Decimal Equivalents

Fraction	Decimal	Fraction	Decimal
1/64	.015625	33/64	.515625
1/32	.03125	17/32	.53125
3/64	.046875	35/64	.546875
1/16	.0625	9/16	.5625
5/64	.078125	37/64	.578125
3/32	.09375	19/32	.59375
7/64	.109375	39/64	.609375
1/8	.125	5/8	.625
9/64	.140625	41/64	.640625
5/32	.15625	21/32	.65625
11/64	.171875	43/64	.671875
3/16	.1875	11/16	.6875
13/64	.203125	45/64	.703125
7/32	.21875	23/32	.71875
15/64	.234375	47/64	.734375
1/4	.25	3/4	.75
17/64	.265625	49/64	.765625
9/32	.28125	25/32	.78125
19/64	.296875	51/64	.796875
5/16	.3125	13/16	.8125
21/64	.328125	53/64	.828125
11/32	.34375	27/32	.84375
23/64	.359375	55/64	.859375
3/8	.375	7/8	.875
25/64	.390625	57/64	.890625
13/32	.40625	29/32	.90625
27/64	.421875	59/64	.921875
7/16	.4375	15/16	.9375
29/64	.453125	61/64	.953125
15/32	.46875	31/32	.96875
31/64	.484375	63/64	.984375
1/2	.5	1	1.

Tables of Decimal Equivalents

Of 7ths, 14ths, and 28ths of an Inch								Of 6ths, 12ths, and 24ths of an Inch							
7th	14th	28th	Decimal	7th	14th	28th	Decimal	6th	12th	24th	Decimal	6th	12th	24th	Decimal
		1	.035714			15	.535714			1	.041667			13	.541666
	1		.071429	4			.571429		1		.083333		7		.583333
		3	.107143			17	.607143			3	.125			15	.625
1			.142857		9		.642867	1			.166666	4			.666666
		5	.178571			19	.678571			5	.208333			17	.708333
	3		.214286	5			.714286		3		.25		9		.75
		7	.25			21	.75			7	.291666			19	.791666
2			.285714		11		.785714	2			.333333	5			.833333
		9	.321429			23	.821429			9	.375			21	.875
	5		.357143	6			.857143		5		.416666		11		.916666
		11	.392857			25	.892857			11	.458333			23	.958333
3			.428571		13		.928571	3			.5				
		13	.464286			27	.964286								
	7		.5												

Shields Decimal

Decimal Equivalents of an Inch of 128ths, 64ths, 32nds, 16ths, 8ths.

Decimal	128	64	32	16	8th	Decimal	128	64	32	16	8th	Decimal	128	64	32	16	8th
.0078125	1					.343750	44	22	11			.6796875	87				
.015625	2	1				.3515625	45					.687500	88	44	22	11	
.0234375	3					.359375	46	23				.6953125	89				
.031250	4	2	1			.3671875	47					.703125	90	45			
.0390625	5					.375000	48	24	12	6	3/8	.7109375	91				
.046875	6	3				.3828125	49					.718750	92	46	23		
.0546875	7					.390625	50	25				.7265625	93				
.062500	8	4	2	1		.3984375	51					.734375	94	47			
.0703125	9					.406250	52	26	13			.7421875	95				
.078125	10	5				.4140625	53					.750000	96	48	24	12	3/4
.0859375	11					.421875	54	27				.7578125	97				
.093750	12	6	3			.4296875	55					.765625	98	49			
.1015625	13					.437500	56	28	14	7		.7734375	99				
.109375	14	7				.4453125	57					.781250	100	50	25		
.1171875	15					.453125	58	29				.7890625	101				
.125000	16	8	4	2	1/8	.4609375	59					.796875	102	51			
.1328125	17					.468750	60	30	15			.8047875	103				
.140625	18	9				.4765625	61					.812500	104	52	26	13	
.1484375	19					.484375	62	31				.8203125	105				
.156250	20	10	5			.4921875	63					.828125	106	53			
.1640625	21					.500000	64	32	16	8	1/2	.8359375	107				
.171875	22	11				.5078125	65					.843750	108	54	27		
.1796875	23					.515625	66	33				.8515625	109				
.187500	24	12	6	3		.5234375	67					.859375	110	55			
.1953125	25					.531250	68	34	17			.8671875	111				
.203125	26	13				.5390625	69					.875000	112	56	28	14	7/8
.2109375	27					.546875	70	35				.8828125	113				
.218750	28	14	7			.5546875	71					.890625	114	57			
.2265625	29					.562500	72	36	18	9		.8984375	115				
.234375	30	15				.5703125	73					.906250	116	58	29		
.2421875	31					.578125	74	37				.9140625	117				
.250000	32	16	8	4	1/4	.5859375	75					.921875	118	59			
.2578125	33					.593750	76	38	19			.9296875	119				
.265625	34	17				.6015625	77					.937500	120	60	30	15	
.2734375	35					.609375	78	39				.9453125	121				
.281250	36	18	9			.6171875	79					.953125	122	61			
.2890625	37					.625000	80	40	20	10	5/8	.9609375	123				
.296875	38	19				.6328125	81					.968750	124	62	31		
.3046875	39					.640625	82	41				.9765625	125				
.312500	40	20	10	5		.6484375	83					.984375	126	63			
.3203125	41					.656250	84	42	21			.9921875	127				
.328125	42	21				.6640625	85					1.000000	128	64	32	16	1 in.
.3359375	43					.671875	86	43									

TABLE FOR CONVERTING NAUTICAL MILES TO STATUTE MILES

Nautical Miles	Statute Miles	Nautical Miles	Statute Miles	Nautical Miles	Statute Miles	Nautical Miles	Statute Miles
1	1.152	14	16.122	27	31.092	40	46.063
2	2.303	15	17.274	28	32.244	41	47.214
3	3.455	16	18.425	29	33.396	42	48.366
4	4.606	17	19.577	30	34.547	43	49.518
5	5.758	18	20.728	31	35.699	44	50.670
6	6.909	19	21.880	32	36.850	45	51.821
7	8.061	20	23.031	33	38.002	46	52.972
8	9.213	21	24.183	34	39.153	47	54.124
9	10.364	22	25.335	35	40.305	48	55.275
10	11.516	23	26.486	36	41.457	49	56.427
11	12.667	24	27.638	37	42.608	50	57.578
12	13.819	25	28.789	38	43.760		
13	14.970	26	29.941	39	44.911		

EVAPORATIVE POWER OF ONE POUND OF VARIOUS FUELS AT ATMOSPHERIC PRESSURE (15 POUNDS)

1 lb. good coal will evaporate 10 lbs. of water. 1 lb. crude petroleum will evaporate 16 lbs. of water. 1 lb. natural gas (25 cubic feet) will evaporate 20 lbs. of water.

22,450 cubic feet of natural gas (atmospheric pressure) is equal to 1 ton of good soft coal.

DECIMAL EQUIVALENTS

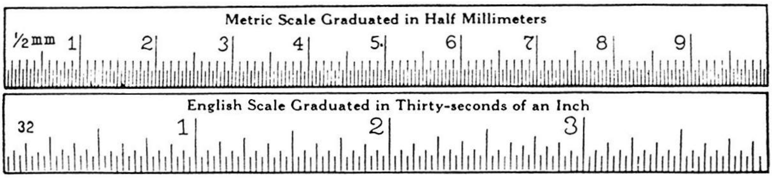
OF MILLIMETERS AND FRACTIONS OF MILLIMETERS

1/100 mm.=.0003937"

Inches		Inches	mm	Inches		Inches	mm
	1-64	.01563	.397		33-64	.51563	13.097
1-32		.03125	.794	17-32		.53125	13.494
	3-64	.04688	1.191		35-64	.54688	13.890
1-16		.0625	1.587	9-16		.5625	14.287
	5-64	.07813	1.984		37-64	.57813	14.684
3-32		.09375	2.381	19-32		.59375	15.081
	7-64	.10938	2.778		39-64	.60938	15.478
1-8		.125	3.175	5-8		.625	15.875
	9-64	.14063	3.572		41-64	.64063	16.272
5-32		.15625	3.969	21-32		.65625	16.669
	11-64	.17188	4.366		43-64	.67188	17.065
3-16		.1875	4.762	11-16		.6875	17.462
	13-64	.20313	5.159		45-64	.70313	17.859
7-32		.21875	5.556	23-32		.71875	18.256
	15-64	.23438	5.953		47-64	.73438	18.653
1-4		.25	6.350	3-4		.75	19.050
	17-64	.26563	6.747		49-64	.76563	19.447
9-32		.28125	7.144	25-32		.78125	19.844
	19-64	.29688	7.541		51-64	.79688	20.240
5-16		.3125	7.937	13-16		.8125	20.637
	21-64	.32813	8.334		53-64	.82813	21.034
11-32		.34375	8.731	27-32		.84375	21.431
	23-64	.35938	9.128		55-64	.85938	21.828
3-8		.375	9.525	7-8		.875	22.225
	25-64	.39063	9.922		57-64	.89063	22.622
13-32		.40625	10.319	29-32		.90625	23.019
	27-64	.42188	10.716		59-64	.92188	23.415
7-16		.4375	11.113	15-16		.9375	23.812
	29-64	.45313	11.509		61-64	.95313	24.209
15-32		.46875	11.906	31-32		.96875	24.606
	31-64	.48438	12.303		63-64	.98438	25.003
1-2		.5	12.700	1		1.00000	25.400

Metric and English Linear Measure

The measuring rules shown below are graduated, in the Metric system and in the English system. This shows at a glance the comparison of the fractions of the Metric and English units, the meter and the inch.



Comparison of English and Metric Scales, Actual Size

TABLE

USEFUL NUMBERS

Square yards,	×.0002067	=acres.
Acres,	×.4840	=square yds.
Cubic inches,	×.00058	=cubic feet.
" feet,	×.03704	= " yds.
Circular inches,	×.00546	=square feet.
Cylindrical inches,	×.0004546	=cubic feet.
" feet,	×.02909	" yds.
Links,	×.22	=yards.
"	×.66	=feet.
Feet,	×1.5	=links.
Width in chains,	×8.	=acres p. mile.
183,346 circular inches,		=1 square ft.
2200 cylindrical inches,		=1 cubic foot.
Cubic feet,	×748	=U. S. galls.
" inches,	×.004329	= " "
Cylindrical feet,	×5.874	= " "
" inches,	×.0034	= " "
U. S. Gallons,	×.13367	=cubic feet.
" "	×231.	= " inches.
Cubic feet,	×.8036	=U. S. bushel.
" inches,	×.000466	= " "
U. S. bushel,	×.9495	=cubic yds.
" "	×1.2446	= " feet.
" "	×2150.42	= " inches.
Cylin. feet of water,	×6.	=U. S. gal's.
Lbs. avoirdupois,	×.009	=cwt. (112.)
" "	×.00045	=tons (2240).
Cubic ft. of water	×62.5	=lbs. avoir.
" ins. "	×.03617	= " "
Cylin. ft. of water,	×49.1	= " "
" ins. "	×.02842	= " "
13.44 U. S. gal's of water,		=1 cwt.
268.8 " " "		=1 ton.
1.8 cubic feet of water,		=1 cwt.
35.88 " " "		=1 ton.
Column of water 12 inches high, 1 inch diameter,		=.341 lbs.

TABLE

Decimal Equivalents of Inches, Feet, and Yards

Frac. of an Inch	Dec. of an Inch	Dec. of a Foot	Ins.	Feet	Yards
1/16 =	.0625 =	.00521	1 =	.0833 =	.0277
1/8 =	.125 =	.01041	2 =	.1668 =	.0555
3/16 =	.1875 =	.01562	3 =	.25 =	.0833
1/4 =	.25 =	.02083	4 =	.3333 =	.1111
5/16 =	.3125 =	.02604	5 =	.4166 =	.1389
3/8 =	.375 =	.08125	6 =	.5 =	.1666
7/16 =	.4375 =	.03645	7 =	.5833 =	.1944
1/2 =	.5 =	.04166	8 =	.666 =	.2222
9/16 =	.5625 =	.04688	9 =	.75 =	.25
5/8 =	.625 =	.05208	10 =	.8333 =	.2778
11/16 =	.6875 =	.05729	11 =	.9166 =	.3055
3/4 =	.75 =	.06250	12 =	1. =	.3333
13/16 =	.8125 =	.06771			
7/8 =	.875 =	.07291			

TABLE

Decimal Equivalents of Ounces and Pounds

Oz.	Lbs.	Oz.	Lbs.	Oz.	Lbs.
1/4 =	.015625	4 =	.25	8½ =	.5313
1/2 =	.03125	4½ =	.2813	9 =	.5625
3/4 =	.046875	5 =	.3125	10 =	.625
1 =	.0625	5½ =	.3438	11 =	.6875
1½ =	.09375	6 =	.375	12 =	.75
2 =	.125	6½ =	.4063	13 =	.8125
2½ =	.15625	7 =	.4375	14 =	.875
3 =	.1875	7½ =	.4688	15 =	.9375
3½ =	.21875	8 =	.5	16 =	1.

Angles Corresponding with Parts of a Circle

Parts	Angle	Parts	Angle	Parts	Angle	Parts	Angle
1	360°	22	16.36°	43	8.37°	78	4.62°
2	180°	23	15.65°	44	8.18°	80	4.5°
3	120°	24	15°	45	8°	82	4.34°
4	90°	25	14.4°	46	7.83°	84	4.29°
5	72°	26	13.85°	47	7.66°	86	4.19°
6	60°	27	13.33°	48	7.5°	88	4.09°
7	51.43°	28	12.86°	49	7.35°	90	4°
8	45°	29	12.41°	50	7.2°	92	3.91°
9	40°	30	12°	52	6.92°	94	3.83°
10	36°	31	11.61°	54	6.67°	96	3.75°
11	32.73°	32	11.25°	56	6.43°	98	3.67°
12	30°	33	10.91°	58	6.21°	100	3.6°
13	27.69°	34	10.59°	60	6°	102	3.53°
14	25.71°	35	10.29°	62	5.81°	104	3.46°
15	24°	36	10°	64	5.63°	106	3.40°
16	22.5°	37	9.73°	66	5.46°	108	3.33°
17	21.18°	38	9.47°	68	5.29°	110	3.27°
18	20°	39	9.23°	70	5.14°	120	3°
19	18.95°	40	9°	72	5°	130	2.77°
20	18°	41	8.78°	74	4.86°	140	2.57°
21	17.14°	42	8.57°	76	4.74°	150	2.4°

Area of Circles — in Square Feet

Diameter	0 in.	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	11 in.
0 ft.	.0000	.0055	.0218	.0491	.0873	.1364	.1964	.2670	.3491	.4418	.5454	.6600
1 "	.7854	.922	1.07	1.23	1.40	1.58	1.77	1.97	2.18	2.41	2.64	2.89
2 "	3.14	3.41	3.69	3.98	4.28	4.59	4.91	5.24	5.59	5.94	6.30	6.68
3 "	7.07	7.47	7.88	8.30	8.73	9.17	9.62	10.08	10.56	11.04	11.54	12.05
4 "	12.57	13.10	13.64	14.19	14.75	15.32	15.90	16.50	17.10	17.72	18.35	18.99
5 ft.	19.64	20.29	20.97	21.65	22.34	23.04	23.76	24.48	25.20	25.97	26.73	27.49
6 "	28.27	29.07	29.87	30.68	31.50	32.34	33.18	34.04	34.91	35.78	36.07	37.57
7 "	38.48	39.41	40.34	41.28	42.24	43.20	44.18	45.17	46.16	47.17	48.19	49.22
8 "	50.27	51.32	52.38	53.46	54.54	55.64	56.75	57.86	58.99	60.13	61.28	62.44
9 "	63.62	64.80	66.00	67.20	68.42	69.64	70.88	72.13	73.39	74.66	75.94	77.24
10 "	78.54	79.85	81.18	82.52	83.86	85.22	86.59	87.97	89.36	90.76	92.18	93.69

NOTE: To find the area of a given circle use the figures at the intersection of the columns (representing feet and inches) which, when combined, equal the diameter of the circle.

Decimal Parts of a Foot in Square Inches

Hundredths of a Sq. Ft.	Square Inches	Hundredths of a Sq. Ft.	Square Inches	Hundredths of a Sq. Ft.	Square Inches	Hundredths of a Sq. Ft.	Square Inches
1	1.44	26	37.4	51	73.4	76	109.4
2	2.88	27	38.9	52	74.9	77	110.9
3	4.32	28	40.3	53	76.3	78	112.3
4	5.76	29	41.8	54	77.8	79	113.8
5	7.20	30	43.2	55	79.2	80	115.2
6	8.64	31	44.6	56	80.6	81	116.6
7	10.1	32	46.1	57	82.1	82	118.1
8	11.5	33	47.5	58	83.5	83	119.5
9	13.0	34	49.0	59	85.0	84	121.0
10	14.4	35	50.4	60	86.4	85	122.4
11	15.8	36	51.8	61	87.8	86	123.8
12	17.3	37	53.3	62	89.3	87	125.3
13	18.7	38	54.7	63	90.7	88	126.7
14	20.2	39	56.2	64	92.2	89	128.2
15	21.6	40	57.6	65	93.6	90	129.6
16	23.0	41	58.0	66	95.0	91	131.0
17	24.5	42	60.5	67	96.5	92	132.5
18	25.9	43	61.9	68	97.4	93	133.9
19	27.4	44	63.4	69	99.9	94	135.4
20	28.8	45	64.8	70	100.	95	136.8
21	30.2	46	66.2	71	102.2	96	138.2
22	31.7	47	67.7	72	103.7	97	139.7
23	33.1	48	69.1	73	105.1	99	141.1
24	34.6	49	70.6	74	106.6	99	142.6
25	36.0	50	72.0	75	108.0	100	144.0

Angles and Distances

Angles and Distances corresponding to the opening of the 2-foot rule.

Ang.	Dis.	Ang.	Dis.	Ang.	Dis.	Ang.	Dis.	Ang.	Dis.	Ang.	Dis.
°	in.	°	in.	°	in.	°	in.	°	in.	°	in.
1	.2	16	3.34	31	6.41	46	9.38	61	12.18	76	14.78
2	.42	17	3.55	32	6.62	47	9.57	62	12.36	77	14.94
3	.63	18	3.75	33	6.82	48	9.76	63	12.54	78	15.11
4	.84	19	3.96	34	7.02	49	9.95	64	12.72	79	15.27
5	1.05	20	4.17	35	7.22	50	10.14	65	12.9	80	15.43
6	1.26	21	4.37	36	7.42	51	10.33	66	13.07	81	15.59
7	1.47	22	4.58	37	7.61	52	10.52	67	13.25	82	15.75
8	1.67	23	4.78	38	7.81	53	10.71	68	13.42	83	15.9
9	1.88	24	4.99	39	8.01	54	10.9	69	13.59	84	16.06
10	2.09	25	5.19	40	8.2	55	11.08	70	13.77	85	16.21
11	2.3	26	5.4	41	8.4	56	11.27	71	13.94	86	16.37
12	2.51	27	5.6	42	8.6	57	11.45	72	14.11	87	16.52
13	2.72	28	5.81	43	8.8	58	11.64	73	14.28	88	16.67
14	2.92	29	6.01	44	8.99	59	11.82	74	14.44	89	16.82
15	3.13	30	6.21	45	9.18	60	12.	75	14.61	90	16.97

Useful Multipliers, Etc.

Diameter of circle × 3.1416 = circumference.
Radius of circle × 6.283185 = circumference.
Square of radius of circle × 3.1416 = area.
Square of diameter of circle × .7854 = area.
Square of circumference × .07958 = area.
Half the circumference × ½ diameter = area.
Circumference of circle × .159155 = radius.
Circumference of circle × .31831 = diameter.
Diameter of circle × .86 = side of inscribed equilateral triangle.
Diameter of circle × .7071 = side of inscribed square.
Circumference of circle × .225 = side of inscribed square.
Circumference of circle × .282 = side of equal square.
Diameter of circle × .8861 = side of equal square.
Base of triangle × ½ altitude = area.
Both diameters × .7854 = area of ellipse.
Surface of sphere × 1/6 diameter = solidity.
Square of diameter of sphere × 3.1416 = surface.
Square of circumference of sphere × .3183 = surface.
Cube of diameter of sphere × .5236 = solidity.
Cube of radius of sphere × 4.1888 = solidity.
Cube of circumference of sphere × .016887 = solidity.
Radius of sphere × 1.1547 = side of inscribed cube.
Area of one of its sides × 6 = surface of cube.
Area of its base × 1-3 altitude = solidity of cone, or pyramid, whether round, square or triangular.

The circumference of a circle multiplied by .282 equals side of a square of same area. Useful in turning round tanks into square.

To find contents in gallons of a square vessel: Multiply number of cylindrical inches by .0034 for wine gallons, by .002785 for ale gallons.

To find contents in gallons of a vessel whose diameter is larger at one end than at the other: Multiply the largest diameter by the smallest in inches. Add one-third of the square of their difference, multiply that sum by the height, and multiply that product by .0034 for wine, or .002785 for ale gallons.

To find capacity of a four sided vessel in gallons: Find cubical contents by multiplying the length, breadth and height in inches and divide product by 231.

The square root of the area of a circle times .56419 equals the radius.

The square root of the area of a circle times 1.12838 equals the diameter.

Doubling the diameter of a pipe increases its capacity four times.

A gallon of water (U. S. Standard) weighs 8½ pounds and contains 231 cubic inches. A cubic foot of water contains 7½ gallons, 1728 cubic inches, and weighs 62½ pounds at a temperature of about 39 degrees Fahrenheit. The weight changes slightly above and below this temperature.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434.

To find the area of a triangle, multiply the base by the altitude and divide the product by 2.

To find the area of a surface, having only two of its sides parallel, multiply one-half sum of the parallel sides by the altitude.

To find the area of a surface whose opposite sides are parallel, multiply the base by the altitude.

To find the diagonal of a square, multiply the length of one side by 1.41421.

To find the diagonal of a cube or the diameter of its circumscribed sphere, multiply the length of a side by 1.7320508.

If a circle is divided by a diameter, each half is called a semicircle, and each half circumference is called a semicircumference.

To find the side of the greatest square that can be inscribed in a given circle, take 7/10 of the diameter and increase it by one per cent of itself.

BARS AND PLATES

Iron	Multiply	contents	in cu.	in. by	.27777	result	will	be weight	in lbs.
Steel	"	"	"	"	.28332	"	"	"	"
Copper	"	"	"	"	.32118	"	"	"	"
Brass	"	"	"	"	.3112	"	"	"	"
Lead	"	"	"	"	.41015	"	"	"	"
Zinc	"	"	"	"	.25318	"	"	"	"
Tin	"	"	"	"	.36562	"	"	"	"
Alu ninum	"	"	"	"	.09375	"	"	"	"

Steam rising from water at its boiling point (212 degrees F.) has a pressure equal to that of the atmosphere at sea level (14.7 pounds per square inch).

24¾ cu. ft. equals 1 perch stone. A perch of stone or brick is 16½ feet long, 1½ feet wide, and 1 foot high.

One acre equals 10 square chains equals 4840 square yards equals 43,560 sq. ft. An acre is equal to a square the side of which is 208.7 feet.

To make a casting of precisely the same size of a broken casting without the original pattern. Put the pieces of broken casting together and cast from them a new casting. Then anneal the new casting, it will expand to the original size of the pattern and thus remain in that expanded state.

To anneal cast iron, heat it in a slow charcoal fire to a dull red heat. Then cover it over, about two inches with fine charcoal; then cover with ashes. Let it lay until cold. Hard cast iron can be softened enough in this way to be filed or drilled.

DEFINITION OF ANGLES

(ALTITUDE.) The perpendicular distance between the bases, or between the vertex and the base, of a solid or plane figure.

(ANGLE.) The difference in direction of two lines which meet or tend to meet. The lines are called sides, and point of meeting, the vertex of the angle.

A right angle is one which is formed by the radius moving, through ¼ of the circumference. It is an angle of 90°.

A straight angle is formed when the radius has moved over ½ of the circumference. It is an angle of 180°.

Acute angle. An angle less than a right angle.

Obtuse angle. An angle greater than a right angle.

Oblique angle. On which is not a right or a straight angle.

Reflex angle. One which is greater than 180°.

Adjacent angle. Two angles are adjacent when they have the same vertex and a common side.

Solid angle. One formed by planes which meet at a point.

Dihedral angle. The opening between two intersecting planes.

Apex. The summit or highest point of an object.

Bisect. To divide into two equal parts.

Bisector. A line which bisects.

Cinquefoil. A figure composed of five leaf-like parts.

Contour. The outline of the general appearance of an object.

Contour Element. An element which is in the contour of an object.

Convergence. Lines extending toward a common point, or planes extending toward a common line.

Circumferences and Areas of Circles

Dia.	Circum.	Area	Dia.	Circum.	Area	Dia.	Circum.	Area
1/16	.1963	.00307	8	25.132	50.265	55	172.788	2375.83
1/8	.3927	.01227	9	28.274	63.617	56	175.929	2463.01
3/16	.5890	.02761	10	31.416	78.540	57	179.071	2551.76
1/4	.7854	.04909	11	34.558	95.033	58	182.212	2642.08
5/16	.9817	.07670	12	37.699	113.097	59	185.354	2733.97
3/8	1.1781	.1104	13	40.840	132.732	60	188.496	2827.43
7/16	1.3744	.1503	14	43.982	153.938	61	191.637	2922.47
1/2	1.5708	.1963	15	47.124	176.715	62	194.779	3019.07
9/16	1.7671	.2485	16	50.265	201.062	63	197.920	3117.25
5/8	1.9635	.3068	17	53.407	226.980	64	201.062	3216.99
11/16	2.1598	.3712	18	56.548	254.469	65	204.204	3318.31
3/4	2.3562	.4418	19	59.690	283.529	66	207.345	3421.19
13/16	2.5525	.5185	20	62.832	314.160	67	210.487	3525.66
7/8	2.7489	.6013	21	65.973	346.361	68	213.628	3631.68
15/16	2.9452	.6903	22	69.115	380.133	69	216.770	3739.28
1	3.1416	.7854	23	72.256	415.476	70	219.912	3848.45
1 1/16	3.3379	.8866	24	75.398	452.390	71	223.053	3959.19
1 1/8	3.5343	.9940	25	78.540	490.875	72	226.195	4071.50
1 3/16	3.7306	1.1075	26	81.681	530.930	73	229.336	4185.39
1 1/4	3.9270	1.2271	27	84.823	572.556	74	232.478	4300.84
1 5/16	4.1233	1.3530	28	87.964	615.753	75	235.620	4417.86
1 3/8	4.3197	1.4848	29	91.106	660.521	76	238.761	4536.46
1 7/16	4.5160	1.6229	30	94.248	706.860	77	241.903	4656.63
1 1/2	4.7124	1.7671	31	97.389	754.769	78	245.044	4778.36
1 5/8	5.1051	2.0739	32	100.531	804.249	79	248.186	4901.68
1 3/4	5.4978	2.4052	33	103.672	855.30	80	251.328	5026.55
1 7/8	5.8905	2.7611	34	106.814	907.92	81	254.469	5153.00
2	6.2832	3.1416	35	109.956	962.11	82	257.611	5281.02
2 1/8	6.6759	3.5465	36	113.097	1017.88	83	260.752	5410.61
2 1/4	7.0686	3.9760	37	116.239	1075.21	84	263.894	5541.77
2 3/8	7.4613	4.4302	38	119.380	1134.11	85	267.035	5674.51
2 1/2	7.8540	4.9087	39	122.522	1194.59	86	270.177	5808.80
2 3/4	8.6394	5.9395	40	125.664	1256.64	87	273.319	5944.68
3	9.4248	7.0686	41	128.805	1320.25	88	276.460	6082.12
3 1/4	10.210	8.2957	42	131.947	1385.44	89	279.602	6221.14
3 1/2	10.995	9.6211	43	135.088	1452.20	90	282.744	6361.73
3 3/4	11.781	11.044	44	138.230	1520.53	91	285.885	6503.88
4	12.566	12.566	45	141.372	1590.43	92	289.027	6647.61
4 1/4	13.351	14.186	46	144.513	1661.90	93	292.168	6792.91
4 1/2	14.137	15.904	47	147.655	1734.94	94	295.310	6939.78
4 3/4	14.922	17.720	48	150.796	1809.56	95	298.452	7088.22
5	15.708	19.635	49	153.938	1885.74	96	301.593	7238.23
5 1/4	16.493	21.647	50	157.080	1963.50	97	304.734	7389.81
5 1/2	17.278	23.758	51	160.221	2042.82	98	307.876	7542.96
5 3/4	18.064	25.967	52	163.363	2123.72	99	311.018	7697.69
6	18.849	28.274	53	166.504	2206.18	100	314.159	7853.98
7	21.991	38.484	54	169.646	2290.22			

To find the circumference and area of any diameter greater than any in the above table:

RULE.—Multiply any diameter given above by the factor 2, 3, 4 or 5, etc., the product of which will be the diameter whose circumference and area is wanted. **EXAMPLE:** What is the circumference of 140? Tabular diameter of 35 × 4 = 140. Tabular circumference of 35 = 109.9 × 4 = 439.6 circumference wanted.

RULE FOR THE AREA.—Multiply the tabular area of tabular diameter by the square of the factor. **EXAMPLE:** What is the area of 140? Tabular area of 35 = 962.11 × 16 (16 is the square of the factor 4) = 15,393.76, area wanted.

THE CIRCLE.—The circumference of a circle is equal to the diameter multiplied by 3.1416. The area of a circle is equal to the square of the diameter multiplied by .7854.

TO HARDEN CAST IRON

Mix 2 pounds of concentrated sulphuric acid and 2 ounces of nitric acid with 2½ gallons of water. Immerse the article at a cherry red heat in this mixture. The surface becomes very hard.

Convenient Multipliers

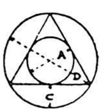
Inches	×0.08333	=feet	Sq. inches	×0.00695	=Sq. feet
Inches	×0.02778	=yards	Sq. inches	×0.0007716	=Sq. yards
Inches	×0.00001578	=miles	Cu. inches	×0.00058	=Cu. feet
			Cu. inches	×0.0000214	=Cu. yards
Feet	×0.3334	=yards	Sq. feet	×144	=Sq. inches
Feet	×0.00019	=miles	Sq. feet	× 0.1112	=Sq. yards
Yards	×36	=inches	Cu. feet	×1728	=Cu. inches
Yards	×3	=feet	Cu. feet	× 0.03704	=Cu. yards
Yards	×0.0005681	=miles	Sq. yards	×1296	=Sq. inches
Miles	×63360	=inches	Sq. yards	× 9	=Sq. feet
Miles	×5280	=feet	Cu. yards	×46656	=Cu. inches
Miles	×1760	=yards	Cu. yards	× 27	=Cu. feet
Avoir. oz.	×0.0625	=pounds	Avoir. lbs.	× 0.0005	=tons
Avoir. oz.	×0.00003125	=tons	Avoir. tons	×32000	=ounces
Avoir. lbs.	×16	=ounces	Avoir. tons	× 2000	=pounds

Useful Rules for Finding Dimensions of Circles, Squares, Etc.

D is diameter of stock necessary to turn shape desired.

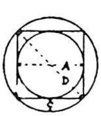
A is distance "across flats."

C is depth of cut into stock turned to correct diameter.



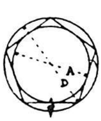
TRIANGLE

A = side x .57735
D = side x 1.1547 = 2A
Side = D x .866
C = A x .5 = D x .25



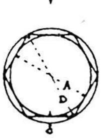
SQUARE

A = side = D x .7071
D = side x 1.4142 = diagonal
Side = D x .7071
C = D x .14645



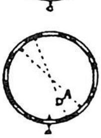
PENTAGON

A = side x 1.3764 = D x .809
D = side x 1.7013 = A x 1.2361
Side = D x .5878
C = D x .0955



HEXAGON

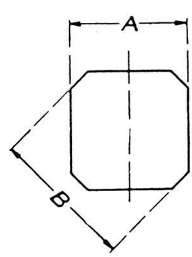
A = side x 1.7321 = D x .866
D = side x 2 = A x 1.1547
Side = D x .5
C = D x .067



OCTAGON

A = side x 2.4142 = D x .9239
D = side x 2.6131 = A x 1.0824
Side = D x .3827
C = D x .038

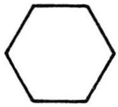
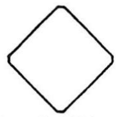
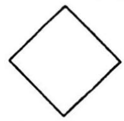
STANDARD ROUND-CORNERED SQUARE HOLES



No. of Square	Size of Square	Size of Shaft
	A	B
1	1	1¼
2	1 1/16	1 5/16
3	1⅛	1⅜
4	1 3/16	1½
5	1¼	1 9/16
6	1 5/16	1⅝
7	1⅜	1¾
8	1 7/16	1 13/16
10	1 9/16	1 15/16
11	1⅝	2
12	1 11/16	2⅛
13	1¾	2¼
14	1 13/16	2 5/16
15	1⅞	2⅜
16	1 15/16	2 7/16
17	2	2½

Distance Across Corners

HEXAGONS AND SQUARES

Distance Across Flats "F"	 Sharp Hexagon F× 1.155	 Pratt & Whitney Practice F× 1.333	 Sharp Corners F× 1.414
1/4	.29	.33	.36
5/16	.36	.41	.44
3/8	.43	.50	.53
7/16	.50	.58	.62
1/2	.57	.66	.71
9/16	.65	.75	.80
5/8	.72	.83	.88
11/16	.79	.91	.97
3/4	.86	1.00	1.06
13/16	.93	1.08	1.15
7/8	1.01	1.16	1.24
15/16	1.08	1.25	1.33
1	1.15	1.33	1.41
1 1/16	1.22	1.42	1.50
1 1/8	1.29	1.50	1.59
1 3/16	1.37	1.58	1.68
1 1/4	1.44	1.66	1.77
1 5/16	1.51	1.75	1.86
1 3/8	1.58	1.83	1.94
1 7/16	1.66	1.92	2.03
1 1/2	1.73	2.00	2.12
1 9/16	1.80	2.08	2.21
1 5/8	1.88	2.16	2.30
1 11/16	1.95	2.25	2.39
1 3/4	2.02	2.33	2.47
1 13/16	2.09	2.42	2.56
1 7/8	2.17	2.50	2.65
1 15/16	2.24	2.58	2.74
2	2.31	2.66	2.83

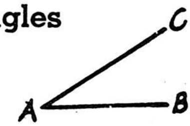
The Electro-Chemical Series of Elements

In the table given below, the elements are electro-positive to the ones which follow them, and will displace them from solutions of their salts.

1. Sodium
2. Barium
3. Calcium
4. Magnesium
5. Beryllium
6. Aluminum
7. Manganese
8. Zinc
9. Iron
10. Nickel
11. Cobalt
12. Lead
13. Bismuth
14. Copper
15. Silver
16. Mercury
17. Platinum
18. Iridium
19. Gold
20. Hydrogen
21. Tin
22. Silicon
23. Antimony
24. Carbon
25. Tungsten
26. Molybdenum
27. Chromium
28. Arsenic
29. Phosphorus
30. Iodine
31. Bromine
32. Chlorine
33. Nitrogen
34. Sulphur
35. Oxygen

Shields Definitions of Angles — Triangles

An angle is the portion of a plane included between two straight lines which meet at a common point. The part of the plane included between AB and AC is called an Angle. AB and AC are its sides, and A is its vertex.



Triangles are divided into classes with reference both to their sides and their angles.

Fig. A—An "Equilateral" Triangle is one which has its three sides equal.

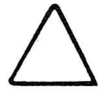


Fig. A.

Fig. B—An "Isosceles" triangle is one which has only two of its sides equal.

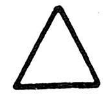


Fig. B.

Fig. C—A "Scalene" triangle is one which has its three sides unequal.


Fig. C.

Fig. D—An "Acute-angled" triangle is one which has its three angles acute; that is, less than a right angle.

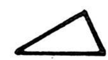


Fig. D.

Fig. E—A "Right Angled" triangle is one which has a right angle. The side opposite the right angle is called the hypothenuse, and the other two sides the base and perpendicular.

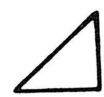


Fig. E.

Fig. F—An "Obtuse-angled" triangle is one which has an obtuse angle; that is, an angle greater than a right angle.


Fig. F.

Fig. G—An "Oblique" angle with the plane of the horizon; a sloping plane, or inclined plane.


Fig. G.

APPROXIMATE CUTTING SPEEDS

Turning and Boring

MATERIAL	Roughing Cutting Speed, Feet per Minute	Finishing Cutting Speed, Feet per Minute	Chasing Cutting Speed, Feet per Minute
Cast-Iron	60	120	50
Mild Machine Steel	80	150	60
Alloy Steel*	50	90	40
Bronze	100	150	70
Brass	200	300	80
Aluminum	250	400	90

Shields Measurements of Angles and Circles

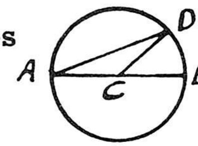


Fig.A.

The greatest line which can be inscribed in a circle is a diameter, hence every chord is less than a diameter.

Fig. A—Let AD be any chord. Draw the radii CA and CD to its extremities. We shall then have AD is less than AC + CD, but AC plus CD is equal to AB; hence AD is less than AB.

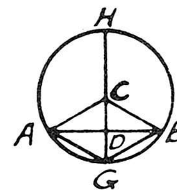


Fig. B.

A radius which is perpendicular to a chord bisects the chord, and also bisects the subtended arc of the chord.

Fig. B—Let AB be any chord, and CG a radius perpendicular to it; then AD will be equal to DB, and the arc AG to the arc GB. For, draw the radii CA, CB and the two right-angled triangles ADC and CDB will have AC equal to CB, and CD common, hence AD is equal to DB.

Again, since AD and DB are equal, CG is a perpendicular erected from the middle of AB; and since G is a point of this perpendicular, the chords AG and GB are equal. And if the chord AG is equal to the chord GB, the arc AG is equal to the arc GB.

The center C, the middle point D of the chord AB, and the middle point G of the subtended arc, are three points of the same straight line, perpendicular to the chord.

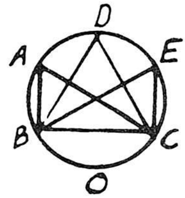


Fig. C.

Fig. C—All the angles, BAC, BDC and BEC, inscribed in the same, segment, are equal; because they are each measured by half of the same arc, BOC.

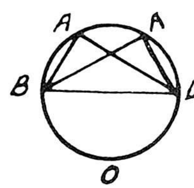


Fig.D.

Fig. D—Every angle, BAD, inscribed in a semicircle, is a right angle; because it is measured by half the semicircumference, BOD, that is, by the fourth part of the whole circumference.

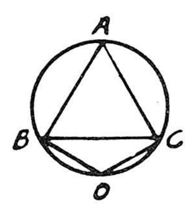


Fig. E.

Fig. E—Every angle, BAC, inscribed in a segment greater than a semicircle, is an acute angle; for it is measured by half the arc BOC, which is less than a semicircle. Hence, every angle, BOC, inscribed in a segment less than a semicircle, is an obtuse angle; for it is measured by half the arc BAC, which is greater than a semicircle,

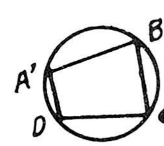


Fig. F.

Fig. F—The opposite angles, A and C, of an inscribed quadrilateral, ABCD, are together equal to two right angles; for the angle, BAD, is measured by half the arc BCD, and the angle, BCD, is measured by half the arc BAD; hence the two angles, BAD and BCD, taken together, are measured by half the circumference, therefore their sum is equal to two right angles.

Shields Inscribed Angles

Fig. A.

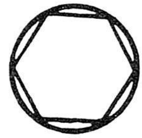


Fig. B.

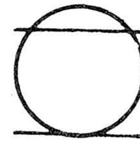


Fig. C.

Fig. A—An inscribed angle is one which has its vertex in a circumference, and is included by two chords of the circle. An inscribed triangle is one which has the vertices of its three angles in the circumference.

Fig. B—A Polygon is said to be inscribed in a circle when the vertices of all the angles are in the circumference. The circumference of the circle is then said to circumscribe the polygon.

Fig. C—The top line is a Secant, a line which meets the circumference in two points, and lies partly within and partly without the circle. The lower line is a Tangent, a line which has but one point in common with the circumference. The point where the tangent touches the circumference is called the point of contact.

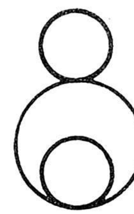


Fig. D.

Fig. D—Two circumferences touch each other when they have but one point in common. The common point is called the point of tangency.

Fig. E—A Polygon is circumscribed about a circle when all its sides are tangents to the circumference. In the same case, the circle is said to be inscribed in the polygon.

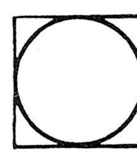
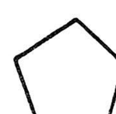


Fig. E.

The circumference of a circle may be described from any center, and with any radius.

Shields Definitions of Polygons



Pentagon.

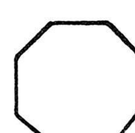
A POLYGON, or rectilineal figure, is a portion of a plane terminated on all sides by straight lines. The sum of the bounding lines is called the perimeter of the polygon.

The polygon of three sides, the simplest of all, is called a Triangle; that of four sides, a Quadrilateral; five sides, a Pentagon; six sides, a Hexagon; seven sides, a Heptagon; eight sides, an Octagon; nine sides, a Nonagon; ten sides, a Decagon; twelve sides, a Dodecagon.

Hexagon.

An Equilateral Polygon is one which has all its sides equal. An Equiangular Polygon is one which has all its angles equal.

Two Polygons are mutually equilateral when they have their sides equal, each to each and placed in the same order: that is to say, when following their bounding lines in the same direction, the first side of one is equal to the first side of the other, the second to the second, the third to the third, and so on. Likewise, two polygons are mutually equiangular when every angle of the one is equal to a corresponding angle of the other, each to each.



Octagon.

Shields Definitions of Quadrilaterals

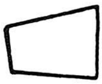


Fig. A.

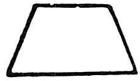


Fig. B.


Fig. C.

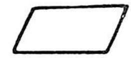


Fig. D.

There are three kinds of Quadrilaterals;

Fig. A—The Trapezium, which has none of its sides parallel.

Fig. B—The Trapezoid, which has only two of its sides parallel. The altitude of a Trapezoid is the perpendicular distance between its two parallel sides.

Fig. C—The Parallelogram, which has its opposite sides parallel.

There are four kinds of Parallelograms;

Fig. D—The Rhomboid, has no right angle.

Fig. E—The Rhombus (lozenge), which is an equilateral rhomboid.

Fig. F—The Rectangle, which is equiangular but not equilateral.

Fig. G—The Square, which is both equilateral and equiangular.

The altitude of a parallelogram is the perpendicular distance between two opposite sides. These sides are called bases.

A "Diagonal" of a figure is a line which joins the vertices of two angles not adjacent (Fig. H.)

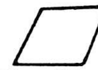


Fig. E.

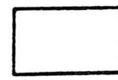


Fig. F.

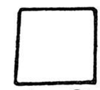


Fig. G.

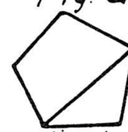


Fig. H.

Shields Definitions of Polyhedrons

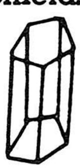


Fig. A.

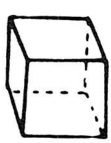


Fig. B.

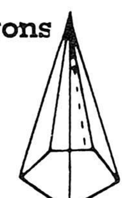


Fig. C.

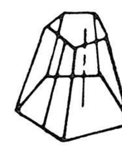


Fig. D.

Polyhedron is a name given to any solid, bounded by Polygons. The bounding polygons are called faces of the polyhedron; and the straight line in which any two adjacent faces meet each other, is called an edge of the polyhedron.

Fig. A—A Prism is a polyhedron in which two of the faces are equal polygons, with their planes and homologous sides parallel, and all the other faces parallelograms.

Fig. B—A Rectangular Parallelopipedon is one whose faces are all rectangles. When all the faces are squares, it is called a Cube, or regular Hexahedron.

Fig. C—A Pyramid is a solid bounded by a polygon, and by triangles meeting at a common point called the Vertex. The Polygon is called the Base; and the triangles, taken together, the convex or lateral surface.

The Pyramid, like the Prism, takes different names according to the form of its base; it may be Triangular, Quadrangular, Pentangular, etc.

Fig. D—If a pyramid is cut by a plane parallel to its base, forming a second base, it is called a Truncated Pyramid, or Frustum of a pyramid.

Shields Definitions of Three Round Bodies

The Cylinder, the Cone and the Sphere, are the three round bodies treated of in the Elements of Geometry.

Fig. A.

Fig. A—A Cylinder is a solid which may be generated by the revolution of a rectangle, ABCD, turning about the fixed side AB. In this movement, the sides AD and BC, continuing always perpendicular to AB, describe the equal circles, DPH and CGQ, which are called the bases of the cylinder, the sides CD, describing at the same time, the convex surface.

The fixed line, AB, is called the axis of the Cylinder, and any section, MNKL, in the cylinder, made by a plane at right angles to the axis, is a circle equal to either of the bases.

While the rectangle ABCD turns about AB, the line KI, perpendicular to AB, describes a circle equal to the base, and this circle is the same as the plane MNKL, perpendicular to the axis at the point I. Every section, QPHG, made by a plane passing through the axis, is a rectangle double the generating rectangle ABCD.

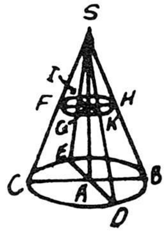


Fig. B.

Fig. B—A Cone is a solid which may be generated by the revolution of a right-angled triangle, SAB, turning about the fixed side SA. In this movement the side AB describes the circle BDCE, called the Base of the cone; and the Hypothenuse SB, describes the convex surface of the cone.

The point S is called the Vertex of the cone, SA the Axis, or the Altitude, and SB the Slant Height. Every section, HKFI, made by a plane at right angles to the axis, is a circle. Every section, EDS, made by a plane passing through the axis, is an Isosceles Triangle double the generating triangle SAB.

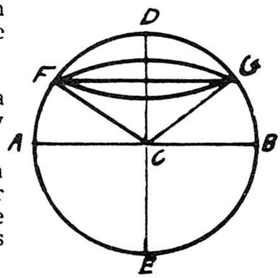


Fig. C.

Fig. C—The Sphere is a solid terminated by a curved surface, all points of which are equally distant from a point within, called the center.

The sphere may be generated by the revolution of a semicircle, DAE, about its diameter DE; for the surface described in this movement, by the semicircumference DAE, will have all its points equally distant from its center C.

While the semicircle DAE, revolving around its diameter, DE, describes the Sphere, any circular sector DCF or FCA, describes a solid called a spherical sector.

SAFETY PLUGS — COMPOSITION AND MELTING POINTS

Tin	Lead	Melts °F.	Tin	Lead	Bismuth	Melts °F.
6	1	381	4	4	1	320
5	1	378	3	3	1	310
4	1	365	2	2	1	292
3	1	340	1	1	1	254
2	1	334	3	5	8	212
1½	1	320	1	1	2	201
			2	3	5	199

MENSURATION

AREA

Square

A = Area — $A = S^2$

$A = \frac{1}{2}d^2$

S = Height — $S = .7071\,d = \sqrt{A}$

d = Diagonal — $D = 1.414S = 1.414\sqrt{A}$

Rectangle

$A = a \times b$

A = Area — $A = a\sqrt{d^2 - a^2} = b\sqrt{d^2 - b^2}$

a = Height — $d = \sqrt{a^2 + b^2}$

b = Width — $a = \sqrt{d^2 - b^2} = A \div b$

d = Diagonal — $b = \sqrt{d^2 - a^2} = A \div a$

Hexagon

A = Area — $A = 2.598 \times S^2 = 2.598.R^2 = 3{,}464r^2$

R = Radius of Circumscribed Circle — $R = s = 1.55 \times r$

r = Radius of Inscribed Circle — $r = .866 \times s = .866\ R$

s = Width of Side — $s = R = 1.155 \times r$

Octagon

A = Area — $A = 4.828 \times s^2 = 2.828.R^2 = 3.314\ r^2$

R = Radius of Circumscribed Circle — $R = 1.307 \times s = 1.082 \times r$

r = Radius of Inscribed Circle — $r = 1.207 \times s = .924R$

s = Width of Side — $s = .765 \times R = .828 \times r$

Circle

A = Area — $A = \pi r^2 = 3.1416 \times r^2 = .7854d^2$

C = Circumference — $C = 2\pi r = 6.2832 \times r = 3.1416d$

r = Radius — $r = \frac{C}{6.2832} = \sqrt{\frac{A}{3.1416}} = .564\sqrt{A}$

d = Diameter — $d = \frac{C}{3.1416} = \sqrt{\frac{A}{.7854}} = 1.128\sqrt{A}$

Circular Sector

L = Length of arc — $L = \frac{ra\ 3.1416}{180} = .01745 \times r \times a = \frac{2A}{r}$

A = Area — $A = \frac{1}{2}r \times L = .008727 \times a \times r^2$

a = Angle in degrees — $a = \frac{57.296 \times L}{r}$

r = Radius — $r = \frac{2A}{L} = \frac{57.296L}{a}$

Circular Ring — $A = \pi(R^2 - r^2) = 3.1416(R^2 - r^2) = 3.1416(R + r)\ (R - r)$

A = Area — $= 7.854(D_2 - d_2) = 7.854\ (D + d)\ (D - d)$

D = Outside diameter

d = Inside diameter

R = Outside radius

VOLUME

Cube

$V = S^3$

S = Dimension of one side — $S = \sqrt[3]{V}$

V = Volume

AREA—*Continued*

Square Prism

V = Volume
a = Length
b = Height
c = Width

$$V = abc$$

$$a = \frac{V}{bc} \quad b = \frac{V}{ac} \quad c = \frac{V}{ab}$$

Cylinder

V = Volume
S = Area of cylindrical surface
A = Area of cylindrical surface and end surfaces
R = Radius of circle
D = Diameter of circle
h = Length of cylinder

$$V = 3.1416 \times R^2h = .7854D^2h$$

$$S = 6.2832Rh = 3.1416Dh$$

$$A = 6.2832R\ (R+h) = 3.1416 \times D(\tfrac{1}{2}D+h)$$

Hollow Cylinder

V = Volume
R = Radius of outer cylinder
r = Radius of inner cylinder
t = Thickness of wall
D = Outside diameter of cylinder
d = Inside diameter of cylinder
h = Length

$$V = 3.1416 \times h(R^2 - r^2) = .7854h(D^2 - d^2)$$

$$= 3.1416 \times ht(2R - t) = 3.1416ht(D - t)$$

$$= 3.1416 \times ht(2r + t) = 3.1416ht\ (d + t)$$

$$= 3.1416 \times ht(R + r) = 1.5708ht(D + d)$$

Sphere

V = Volume
A = Area of surface
r = Radius
d = Diameter

$$V = \frac{4\pi r^3}{3} = \frac{\pi d^3}{6} = 4.1888 \times r^3$$

$$= .5236d^3$$

$$A = 4\pi r^2 = \pi d^2 = 12.5664r^2$$

$$= 3.1416d^2$$

$$r = \sqrt[3]{\frac{3V}{4\pi}} = .6204\sqrt[3]{V}$$

Hollow Sphere

V = Volume
r = Inside radius
R = Outer radius
d = Inside diameter
D = Outside diameter

$$V = \frac{4\pi}{3}(R^3 - r^3) = 4.1888(R^3 - r^3)$$

$$= \frac{\pi}{6}(D^3 - d^3) = .5236\ (D^3 - d^3)$$

Cone

V = Volume
A = Area of conical surface
D = Diameter of base
R = Radius of base
H = Height
S = Length of side

$$V = \frac{3.1416 \times R^2 \times H}{3} =$$

$$1.0472 \times R^2 \times H =$$

$$.2618 \times D^2 \times H$$

$$A = 3.1416 \times R\ \sqrt{R^2+H^2}$$

$$= 3.1416 \times R \times S$$

$$= 1.5708 \times D \times S$$

$$S = \sqrt{R^2+H^2} = \sqrt{\frac{D^2}{4}+H^2}$$

VOLUME—*Continued*

Frustum of Cone

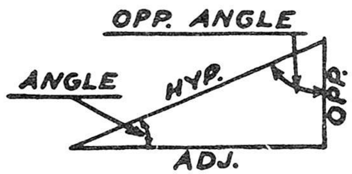
V = Volume
A = Area of Conical Surface
D = Diameter of base
d = Diameter of top
H = Height
S = Length of side
R = Radius of base
r = Radius of top
a = R − r

$V = 1.0472 \times H(R^2 + R \times r + r^2) = .2618 \times h\ (D^2 + D \times d + d^2).$

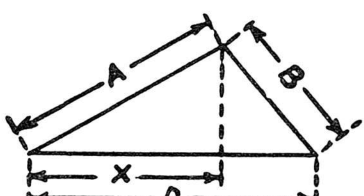
$A = 3.1416 \times S(R + r) = 1.5708 \times S(D + d)$

$S = \sqrt{a^2 + H^2} = \sqrt{(R - r)^2 + H^2}$

Table for Solving Right Angled Triangles



PARTS GIVEN	PARTS TO BE FOUND				
	Hyp.	Adj.	Opp.	Angle	Opp. Angle
Hyp. & Adj.	———	———	$\sqrt{\text{Hyp.}^2\text{-Adj.}^2}$	$\text{Cos.} = \frac{\text{Adj.}}{\text{Hyp.}}$	$\text{Sin.} = \frac{\text{Adj.}}{\text{Hyp.}}$
Hyp. & Opp.	———	$\sqrt{\text{Hyp.}^2\text{-Opp.}^2}$	———	$\text{Sin.} = \frac{\text{Opp.}}{\text{Hyp.}}$	$\text{Cos.} = \frac{\text{Opp.}}{\text{Hyp.}}$
Hyp. & Angle	———	Hyp. x Cos.	Hyp. x Sin.	———	90°-Angle
Adj. & Opp.	$\sqrt{\text{Adj.}^2+\text{Opp.}^2}$	———	———	$\text{Tan.} = \frac{\text{Opp.}}{\text{Adj.}}$	$\text{Cot.} = \frac{\text{Opp.}}{\text{Adj.}}$
Adj. & Angle	$\frac{\text{Adj.}}{\text{Cos.}}$	———	Adj. x Tan.	———	90°-Angle
Opp. & Angle	$\frac{\text{Opp.}}{\text{Sin.}}$	Opp. x Cot.	———	———	90°-Angle



When A, B & D Are Given $X = \frac{D^2 + A^2 - B^2}{2D}$

EXPANSION OF BODIES BY HEAT

The coefficient of linear expansion (ϵ) is the change in length, per unit of length, for a change of one degree of temperature. The coefficient of surface expansion is approximately two times the linear coefficient, and the coefficient of volume expansion, for solids, is approximately three times the linear coefficient.

A bar, free to move, will increase in length with an increase in temperature and will decrease in length with a decrease in temperature. The change in length will be ϵtl, where ϵ is the coefficient of linear expansion, t the change in temperature, and l the length. If the ends of a bar are fixed, a change in temperature (t) will cause a change in the unit stress of $E\epsilon t$, and in the total (stress of) $AE\epsilon t$, where A is the cross sectional area of the bar and E the modulus of elasticity.

The following table gives the coefficient of linear expansion for 100°, or 100 times the value indicated above.

Example: A piece of medium steel is exactly 40 feet long at 60° F. Find the length at 90° F. assuming the ends free to move.

$$\text{Change of length} = \epsilon tl = \frac{.00067 \times 30 \times 40}{100} = .00804 \text{ foot.}$$

The length at 90° F. is 40.00804 feet.

Example: A piece of medium steel is exactly 40 feet long and the ends are fixed. If the temperature increases 30° F., what is the resulting change in the unit stress?

$$\text{Change in unit stress} = E\epsilon t = \frac{29{,}000{,}000 \times .00067 \times 30}{100} = 5830 \text{ lbs. per sq. in.}$$

COEFFICIENTS OF EXPANSION FOR 100 DEGREES = 100ϵ

Substances	Linear Expansion Centigrade	Linear Expansion Fahrenheit	Substances	Linear Expansion Centigrade	Linear Expansion Fahrenheit
METALS AND ALLOYS			Cement, portland	.00107	.00069
Aluminum, wrought	.00231	.00128	Concrete	.00143	.00079
Brass	.00188	.00104	Granite	.00084	.00047
Bronze	.00181	.00101	Limestone	.00080	.00044
Copper	.00168	.00093	Marble	.00100	.00056
Iron, cast, gray	.00106	.00059	Plaster	.00166	.00092
Iron, wrought	.00120	.00067	Rubble masonry	.00063	.00035
Iron, wire	.00124	.00069	Sandstone	.00110	.00061
Lead	.00286	.00159	Slate	.00104	.00058
Nickel	.00126	.00070	**TIMBER**		
Steel, cast	.00110	.00061	Fir, parallel to fiber	.00037	.00021
Steel, hard	.00132	.00073	Maple, parallel to fiber	.00064	.00036
Steel, medium	.00120	.00067	Oak, parallel to fiber	.00049	.00027
Steel, soft	.00110	.00061	Pine, parallel to fiber	.00054	.00030
Zinc, rolled	.00311	.00173	Fir, perpendicular to fiber	.0058	.0032
STONE AND MASONRY			Maple, perpendicular to fiber	.0048	.0027
Ashlar masonry	.00063	.00035	Oak, perpendicular to fiber	.0054	.0030
Brick masonry	.00055	.00031	Pine, perpendicular to fiber	.0034	.0019

EXPANSION OF WATER
MAXIMUM DENSITY = 1

C°	Volume	C°	Volume	C°	Volume	C°	Volume	C°	Volume	C°	Volume
0	1.000126	10	1.000257	30	1.004234	50	1.011877	70	1.022384	90	1.035829
4	1.000000	20	1.001732	40	1.007627	60	1.016954	80	1.029003	100	1.043116

1. The Tetraedron, or *equilateral pyramid*, is a solid bounded by four equal equilateral triangles.

2. The Hexaedron, or *Cube*, is a solid bounded by six equal squares.

3. The Octaedron, is a solid bounded by eight equal equilateral triangles.

4. The Dodecaedron, is a solid bounded by twelve equal and regular pentagons.

5. The Isosaedron is a solid bounded by twenty equal equilateral triangles.

This formula gives, for the diedral angle formed by any two adjacent faces of the

Tetraedron	70° 31′ 42″
Hexaedron	90°
Octaedron	109° 28′ 18″
Dodecaedron	116° 33′ 54″
Icosaedron	138° 11′ 23″

Having thus found the diedral angle included between the adjacent faces, we can easily calculate the perpendicular let fall from the centre of the polyedron on one of its faces, when the faces themselves are known.

REGULAR POLYGONS

Let the areas of the regular polygons whose sides are unity, or 1, be calculated and arranged in the following table.

Names	Sides	Areas	Names	Sides	Areas
Triangle	3	0.4330127	Octagon	8	4.8284271
Square	4	1.0000000	Nonagon	9	6.1818242
Pentagon	5	1.7204774	Decagon	10	7.6942088
Hexagon	6	2.5980762	Undecagon	11	9.3656399
Heptagon	7	3.6339124	Dodecagon	12	11.1961524

POLYHEDRONS

We have subjoined the computation of these polygons, carried on till they agree as far as the seventh place of decimals.

Number of Sides	Inscribed Polygons	Circumscribed Polygons
4	2.0000000	4.0000000
8	2.8284271	3.3137085
16	3.0614674	3.1825979
32	3.1214451	3.1517249
64	3.1365485	3.1441184
128	3.1403311	3.1422236
256	3.1412772	3.1417504
512	3.1415138	3.1416321
1024	3.1415729	3.1416025
2048	3.1415877	3.1415951
4096	3.1415914	3.1415933
8192	3.1415923	3.1415928
16384	3.1415925	3.1415927
32768	3.1415926	3.1415926

A Table of Regular Polyedrons Whose Edges Are 1

NAMES.	NO. OF FACES.	SURFACE.	SOLIDITY.
Tetraedron	4	1.7320508	0.1178513
Hexaedron	6	6.0000000	1.0000000
Octaedron	8	3.4641016	0.4714045
Dodecaedron	12	20.6457288	7.6631189
Icosaedron	20	8.6602540	2.1816950

Solution of Triangles by Natural Lines

Parts Given	TO OBTAIN				
	Angle	Adj. Side	Op. Side	Hypoth.	Op. Angle
Op. & Hyp.	Sin. $= \frac{\text{Op.}}{\text{Hyp.}}$	$\sqrt{\text{Hyp.}^2 - \text{Op.}^2}$			Cos. $= \frac{\text{Op.}}{\text{Hyp}}$
Op. & Adj.	Tan. $= \frac{\text{Op.}}{\text{Adj.}}$			$\sqrt{\text{Op.}^2 + \text{Adj.}^2}$	Cot. $= \frac{\text{Op.}}{\text{Adj.}}$
Adj. & Hyp.	Cos. $= \frac{\text{Adj.}}{\text{Hyp.}}$				
Ang. & Op.		Op. × Cot.		Op. ÷ Sin.	90°—Ang.
Ang. & Adj.			Adj. × Tan.	Adj. ÷ Cos.	90°—Ang.
Ang. & Hyp.		Hyp. × Cos.	Hyp. × Sin.		90°—Ang.

TRIGONOMETRIC FUNCTIONS

QUICK REFERENCE TABLE

Degrees	Sine	Tangent	Cotangent	Cosine	Degrees
0	.0000	.0000	....	1.000	90
1	.0175	.0175	57.29	.9998	89
2	.0349	.0349	28.636	.9994	88
3	.0523	.0524	19.081	.9986	87
4	.0698	.0699	14.301	.9976	86
5	.0872	.0875	11.430	.9962	85
6	.1045	.1051	9.5144	.9945	84
7	.1219	.1228	8.1443	.9925	83
8	.1392	.1405	7.1154	.9903	82
9	.1564	.1584	6.3138	.9877	81
10	.1736	.1763	5.6713	.9848	80
11	.1908	.1944	5.1446	.9816	79
12	.2079	.2126	4.7046	.9781	78
13	.2250	.2309	4.3315	.9744	77
14	.2419	.2493	4.0108	.9703	76
15	.2588	.2679	3.7321	.9659	75
16	.2756	.2867	3.4874	.9613	74
17	.2924	.3057	3.2709	.9563	73
18	.3090	.3249	3.0777	.9511	72
19	.3256	.3443	2.9042	.9455	71
20	.3420	.3640	2.7475	.9397	70
21	.3584	.3839	2.6051	.9336	69
22	.3746	.4040	2.4751	.9272	68
23	.3907	.4245	2.3559	.9205	67
24	.4067	.4452	2.2460	.9135	66
25	.4226	.4663	2.1445	.9063	65
26	.4384	.4877	2.0503	.8988	64
27	.4540	.5095	1.9626	.8910	63
28	.4695	.5317	1.8807	.8829	62
29	.4848	.5543	1.8040	.8746	61
30	.5000	.5774	1.7321	.8660	60
31	.5150	.6009	1.6643	.8572	59
32	.5299	.6249	1.6003	.8480	58
33	.5446	.6494	1.5399	.8387	57
34	.5592	.6745	1.4826	.8290	56
35	.5736	.7002	1.4281	.8192	55
36	.5878	.7265	1.3764	.8090	54
37	.6018	.7536	1.3270	.7986	53
38	.6157	.7813	1.2799	.7880	52
39	.6293	.8098	1.2349	.7771	51
40	.6428	.8391	1.1918	.7660	50
41	.6561	.8693	1.1504	.7547	49
42	.6691	.9004	1.1106	.7431	48
43	.6820	.9325	1.0724	.7314	47
44	.6947	.9657	1.0355	.7193	46
45	.7071	1.0000	1.0000	.7071	45
Degrees	Cosine	Cotangent	Tangent	Sine	Degrees

AN "ATMOSPHERE," $14\frac{7}{10}$ lbs. at 62° F., is equal to a column of mercury 30" high, or a column of water $33\frac{9}{10}$ feet high. Approximately each foot of elevation = $\frac{1}{2}$ lb. pressure per square inch, but to find the **exact** pressure in lbs. per square inch of a column of water × the height in feet by $\frac{434}{1000}$. $\frac{.434}{1000}$ is the decimal fraction of the lb. pressure per square inch of a column of water 1 foot high at 62° F. **Example:** 100 feet height of column × .434 = $43\frac{4}{10}$ lb. pressure.

TRIGONOMETRIC FUNCTIONS

NATURAL SINES AND COSINES

Degrees	SINE 0′	10′	20′	30′	40′	50′	60′	
0	0.00000	0.00291	0.00582	0.00873	0.01164	0.01454	0.01745	89
1	0.01745	0.02036	0.02327	0.02618	0.02908	0.03199	0.03490	88
2	0.03490	0.03781	0.04071	0.04362	0.04653	0.04943	0.05234	87
3	0.05234	0.05524	0.05814	0.06105	0.06395	0.06685	0.06976	86
4	0.06976	0.07266	0.07556	0.07846	0.08136	0.08426	0.08716	85
5	0.08716	0.09005	0.09295	0.09585	0.09874	0.10164	0.10453	84
6	0.10453	0.10742	0.11031	0.11320	0.11609	0.11898	0.12187	83
7	0.121[illegible]	0.12476	0.12764	0.13053	0.13341	0.13629	0.13917	82
8	0.13917	0.14205	0.14493	0.14781	0.15069	0.15356	0.15643	81
9	0.15643	0.15931	0.16218	0.16505	0.16792	0.17078	0.17365	80
10	0.17365	0.17651	0.17937	0.18224	0.18500	0.18795	0.19081	79
11	0.19081	0.19366	0.19652	0.19937	0.20222	0.20507	0.20791	78
12	0.20791	0.21076	0.21360	0.21644	0.21928	0.22212	0.22495	77
13	0.22495	0.22778	0.23062	0.23345	0.23627	0.23910	0.24192	76
14	0.24192	0.24474	0.24756	0.25038	0.25320	0.25601	0.25882	75
15	0.25882	0.26163	0.26443	0.26724	0.27004	0.27284	0.27564	74
16	0.27564	0.27843	0.28123	0.28402	0.28680	0.28959	0.29237	73
17	0.29237	0.29515	0.29793	0.30071	0.30348	0.30625	0.30902	72
18	0.30902	0.31178	0.31454	0.31730	0.32006	0.32282	0.32557	71
19	0.32557	0.32832	0.33106	0.33381	0.33655	0.33929	0.34202	70
20	0.34202	0.34475	0.34748	0.35021	0.35293	0.35565	0.35837	69
21	0.35837	0.36108	0.36379	0.36650	0.36921	0.37191	0.37461	68
22	0.37461	0.37730	0.37999	0.38268	0.38537	0.38805	0.39073	67
23	0.39073	0.39341	0.39608	0.39875	0.40142	0.40408	0.40674	66
24	0.40674	0.40939	0.41204	0.41469	0.41734	0.41998	0.42262	65
25	0.42262	0.42525	0.42788	0.43051	0.43318	0.43575	0.43837	64
26	0.43837	0.44098	0.44359	0.44620	0.44880	0.45140	0.45399	63
27	0.45399	0.45658	0.45917	0.46175	0.46433	0.46690	0.46947	62
28	0.46947	0.47204	0.47460	0.47716	0.47971	0.48226	0.48481	61
29	0.48481	0.48735	0.48989	0.49242	0.49495	0.49748	0.50000	60
30	0.50000	0.50252	0.50503	0.50754	0.51004	0.51254	0.51504	59
31	0.51504	0.51753	0.52002	0.52250	0.52498	0.52745	0.52992	58
32	0.52992	0.53238	0.53484	0.53730	0.53975	0.54220	0.54464	57
33	0.54464	0.54708	0.54951	0.55194	0.55436	0.55678	0.55919	56
34	0.55919	0.56160	0.56401	0.56641	0.56880	0.57119	0.57358	55
35	0.57358	0.57596	0.57833	0.58070	0.58307	0.58543	0.58779	54
36	0.58779	0.59014	0.59248	0.59482	0.59716	0.59949	0.60182	53
37	0.60182	0.60414	0.60645	0.60876	0.61107	0.61337	0.61566	52
38	0.61566	0.61795	0.62024	0.62251	0.62479	0.62706	0.62932	51
39	0.62932	0.63158	0.63383	0.63608	0.63832	0.64056	0.64279	50
40	0.64279	0.64501	0.64723	0.64945	0.65166	0.65386	0.65606	49
41	0.65606	0.65825	0.66044	0.66262	0.66480	0.66697	0.66913	48
42	0.66913	0.67129	0.67344	0.67559	0.67773	0.67987	0.68200	47
43	0.68200	0.68412	0.68624	0.68835	0.69046	0.69256	0.69466	46
44	0.69466	0.69675	0.69883	0.70091	0.70298	0.70505	0.70711	45
	60′	50′	40′	30′	20′	10′	0′	Degrees
	COSINE							

NATURAL COSINES AND SINES

Degrees	COSINE 0′	10′	20′	30′	40′	50′	60′	
0	1.00000	1.00000	0.99998	0.99996	0.99993	0.99989	0.99985	89
1	0.99985	0.99979	0.99973	0.99966	0.99958	0.99949	0.99939	88
2	0.99939	0.99929	0.99917	0.99905	0.99892	0.99878	0.99863	87
3	0.99863	0.99847	0.99831	0.99813	0.99795	0.99776	0.99756	86
4	0.99756	0.99736	0.99714	0.99692	0.99668	0.99644	0.99619	85
5	0.99619	0.99594	0.99567	0.99540	0.99511	0.99482	0.99452	84
6	0.99452	0.99421	0.99390	0.99357	0.99324	0.99290	0.99255	83
7	0.99255	0.99219	0.99182	0.99144	0.99106	0.99067	0.99027	82
8	0.99027	0.98986	0.98944	0.98902	0.98858	0.98814	0.98769	81
9	0.98769	0.98723	0.98676	0.98629	0.98580	0.98531	0.98481	80
10	0.98481	0.98430	0.98378	0.98325	0.98272	0.98218	0.98163	79
11	0.98163	0.98107	0.98050	0.97992	0.97934	0.97875	0.97815	78
12	0.97815	0.97754	0.97692	0.97630	0.97566	0.97502	0.97437	77
13	0.97437	0.97371	0.97304	0.97237	0.97169	0.97100	0.97030	76
14	0.97030	0.96959	0.96887	0.96815	0.96742	0.96667	0.96593	75
15	0.96593	0.96517	0.96440	0.96363	0.96285	0.96206	0.96126	74
16	0.96126	0.96046	0.95964	0.95882	0.95799	0.95715	0.95630	73
17	0.95630	0.95545	0.95459	0.95372	0.95284	0.95195	0.95106	72
18	0.95106	0.95015	0.94924	0.94832	0.94740	0.94646	0.94552	71
19	0.94552	0.94457	0.94361	0.94264	0.94167	0.94068	0.93969	70
20	0.93969	0.93869	0.93769	0.93667	0.93565	0.93462	0.93358	69
21	0.93358	0.93253	0.93148	0.93042	0.92935	0.92827	0.92718	68
22	0.92718	0.92609	0.92499	0.92388	0.92276	0.92164	0.92050	67
23	0.92050	0.91936	0.91822	0.91706	0.91590	0.91472	0.91355	66
24	0.91355	0.91236	0.91116	0.90996	0.90875	0.90753	0.90631	65
25	0.90631	0.90507	0.90383	0.90259	0.90133	0.90007	0.89879	64
26	0.89879	0.89752	0.89623	0.89493	0.89363	0.89232	0.89101	63
27	0.89101	0.88968	0.88835	0.88701	0.88566	0.88431	0.88295	62
28	0.88295	0.88158	0.88020	0.87882	0.87743	0.87603	0.87462	61
29	0.87462	0.87321	0.87178	0.87036	0.86892	0.86748	0.86603	60
30	0.86603	0.86457	0.86310	0.86163	0.86115	0.85866	0.85717	59
31	0.85717	0.85567	0.85416	0.85264	0.85112	0.84959	0.84805	58
32	0.84805	0.84650	0.84495	0.84339	0.84182	0.84025	0.83867	57
33	0.83867	0.83708	0.83549	0.83389	0.83228	0.83066	0.82904	56
34	0.82904	0.82741	0.82577	0.82413	0.82248	0.82082	0.81915	55
35	0.81915	0.81748	0.81580	0.81412	0.81242	0.81072	0.80902	54
36	0.80902	0.80730	0.80558	0.80386	0.80212	0.80038	0.79864	53
37	0.79864	0.79688	0.79512	0.79335	0.79158	0.78980	0.78801	52
38	0.78801	0.78622	0.78442	0.78261	0.78079	0.77897	0.77715	51
39	0.77715	0.77531	0.77347	0.77162	0.76977	0.76791	0.76604	50
40	0.76604	0.76417	0.76229	0.76041	0.75851	0.75661	0.75471	49
41	0.75471	0.75280	0.75088	0.74896	0.74703	0.74509	0.74314	48
42	0.74314	0.74120	0.73924	0.73728	0.73531	0.73333	0.73135	47
43	0.73135	0.72937	0.72737	0.72537	0.72337	0.72136	0.71934	46
44	0.71934	0.71732	0.71529	0.71325	0.71121	0.70916	0.70711	45
	60′	50′	40′	30′	20′	10′	0′	Degrees
	SINE							

NATURAL TANGENTS AND COTANGENTS

Degrees	TANGENT 0′	10′	20′	30′	40′	50′	60′	
0	0.00000	0.00291	0.00582	0.00873	0.01164	0.01455	0.01746	89
1	0.01746	0.02036	0.02328	0.02619	0.02910	0.03201	0.03492	88
2	0.03492	0.03783	0.04075	0.04366	0.04658	0.04949	0.05241	87
3	0.05241	0.05533	0.05824	0.06115	0.06408	0.06700	0.06993	86
4	0.06993	0.07285	0.07578	0.07870	0.08163	0.08456	0.08749	85
5	0.08749	0.09042	0.09335	0.09629	0.09923	0.10216	0.10510	84
6	0.10510	0.10805	0.11099	0.11394	0.11688	0.11983	0.12278	83
7	0.12278	0.12574	0.12869	0.13165	0.13461	0.13758	0.14054	82
8	0.14054	0.14351	0.14648	0.14945	0.15243	0.15540	0.15838	81
9	0.15838	0.16137	0.16435	0.16734	0.17033	0.17333	0.17633	80
10	0.17633	0.17933	0.18233	0.18534	0.18835	0.19136	0.19438	79
11	0.19438	0.19740	0.20042	0.20345	0.20648	0.20952	0.21256	78
12	0.21256	0.21560	0.21864	0.22169	0.22475	0.22781	0.23087	77
13	0.23087	0.23393	0.23700	0.24008	0.24316	0.24624	0.24933	76
14	0.24933	0.25242	0.25552	0.25862	0.26172	0.26483	0.26795	75
15	0.26795	0.27107	0.27419	0.27732	0.28046	0.28360	0.28675	74
16	0.28675	0.28990	0.29305	0.29621	0.29938	0.30255	0.30573	73
17	0.30573	0.30891	0.31210	0.31530	0.31850	0.32171	0.32492	72
18	0.32492	0.32814	0.33136	0.33460	0.33783	0.34108	0.34433	71
19	0.34433	0.34758	0.35085	0.35412	0.35740	0.36068	0.36397	70
20	0.36397	0.36727	0.37057	0.37388	0.37720	0.38053	0.38386	69
21	0.38386	0.38721	0.39055	0.39391	0.39727	0.40065	0.40403	68
22	0.40403	0.40741	0.41081	0.41421	0.41763	0.42105	0.42447	67
23	0.42447	0.42791	0.43136	0.43481	0.43828	0.44175	0.44523	66
24	0.44523	0.44872	0.45222	0.45573	0.45924	0.46277	0.46631	65
25	0.46631	0.46985	0.47341	0.47698	0.48055	0.48414	0.48773	64
26	0.48773	0.49134	0.49495	0.49858	0.50222	0.50587	0.50953	63
27	0.50953	0.51320	0.51688	0.52057	0.52427	0.52798	0.53171	62
28	0.53171	0.53545	0.53920	0.54296	0.54674	0.55051	0.55431	61
29	0.55431	0.55812	0.56194	0.56577	0.56962	0.57348	0.57735	60
30	0.57735	0.58124	0.58513	0.58905	0.59297	0.59691	0.60086	59
31	0.60086	0.60483	0.60881	0.61280	0.61681	0.62083	0.62487	58
32	0.62487	0.62892	0.63299	0.63707	0.64117	0.64528	0.64941	57
33	0.64941	0.65355	0.65771	0.66189	0.66608	0.67028	0.67451	56
34	0.67451	0.67875	0.68301	0.68728	0.69157	0.69588	0.70021	55
35	0.70021	0.70455	0.70891	0.71329	0.71769	0.72211	0.72654	54
36	0.72654	0.73100	0.73547	0.73996	0.74447	0.74900	0.75355	53
37	0.75355	0.75812	0.76272	0.76733	0.77196	0.77661	0.78129	52
38	0.78129	0.78598	0.79070	0.79544	0.80020	0.80498	0.80978	51
39	0.80978	0.81461	0.81946	0.82434	0.82923	0.83415	0.83910	50
40	0.83910	0.84407	0.84906	0.85408	0.85912	0.86419	0.86929	49
41	0.86929	0.87441	0.87955	0.88473	0.88992	0.89515	0.90040	48
42	0.90040	0.90569	0.91099	0.91633	0.92170	0.92709	0.93252	47
43	0.93252	0.93797	0.94345	0.94896	0.95451	0.96008	0.96569	46
44	0.96569	0.97133	0.97700	0.98270	0.98843	0.99420	1.00000	45
	60′	50′	40′	30′ COTANGENT	20′	10′	0′	Degrees

NATURAL COTANGENTS AND TANGENTS

Degrees	COTANGENT 0′	10′	20′	30′	40′	50′	60′	
0	∞	343.77371	171.88540	114.58865	85.93979	68.75009	57.28996	89
1	57.28996	49.10388	42.96408	38.18846	34.36777	31.24158	28.63625	88
2	28.63625	26.43160	24.54176	22.90377	21.47040	20.20555	19.08114	87
3	19.08114	18.07498	17.16934	16.34986	15.60478	14.92442	14.30067	86
4	14.30067	13.72674	13.19688	12.70621	12.25051	11.82617	11.43005	85
5	11.43005	11.05943	10.71191	10.38540	10.07803	9.78817	9.51436	84
6	9.51436	9.25530	9.00983	8.77689	8.55555	8.34496	8.14435	83
7	8.14435	7.95302	7.77035	7.59575	7.42871	7.26873	7.11537	82
8	7.11537	6.96823	6.82694	6.69116	6.56055	6.43484	6.31375	81
9	6.31375	6.19703	6.08444	5.97576	5.87080	5.76937	5.67128	80
10	5.67128	5.57638	5.48451	5.39552	5.30928	5.22566	5.14455	79
11	5.14455	5.06584	4.98940	4.91516	4.84300	4.77286	4.70463	78
12	4.70463	4.63825	4.57363	4.51071	4.44942	4.38969	4.33148	77
13	4.33148	4.27471	4.21933	4.16530	4.11256	4.06107	4.01078	76
14	4.01078	3.96165	3.91364	3.86671	3.82083	3.77595	3.73205	75
15	3.73205	3.68909	3.64705	3.60588	3.56557	3.52609	3.48741	74
16	3.48741	3.44951	3.41236	3.37594	3.34023	3.30521	3.27085	73
17	3.27085	3.23714	3.20406	3.17159	3.13972	3.10842	3.07768	72
18	3.07768	3.04749	3.01783	2.98869	2.96004	2.93189	2.90421	71
19	2.90421	2.87700	2.85023	2.82391	2.79802	2.77254	2.74748	70
20	2.74748	2.72281	2.69853	2.67462	2.65109	2.62791	2.60509	69
21	2.60509	2.58261	2.56046	2.53865	2.51715	2.49597	2.47509	68
22	2.47509	2.45451	2.43422	2.41421	2.39449	2.37504	2.35585	67
23	2.35585	2.33693	2.31826	2.29984	2.28167	2.26374	2.24604	66
24	2.24604	2.22857	2.21132	2.19430	2.17749	2.16090	2.14451	65
25	2.14451	2.12832	2.11233	2.09654	2.08094	2.06553	2.05030	64
26	2.05030	2.03526	2.02039	2.00569	1.99116	1.97680	1.96261	63
27	1.96261	1.94858	1.93470	1.92098	1.90741	1.89400	1.88073	62
28	1.88073	1.86760	1.85462	1.84177	1.82907	1.81649	1.80405	61
29	1.80405	1.79174	1.77955	1.76749	1.75556	1.74375	1.73205	60
30	1.73205	1.72047	1.70901	1.69766	1.68643	1.67530	1.66428	59
31	1.66428	1.65337	1.64256	1.63185	1.62125	1.61074	1.60033	58
32	1.60033	1.59002	1.57981	1.56969	1.55966	1.54972	1.53987	57
33	1.53987	1.53010	1.52043	1.51084	1.50133	1.49190	1.48256	56
34	1.48256	1.47330	1.46411	1.45501	1.44598	1.43703	1.42815	55
35	1.42815	1.41934	1.41061	1.40195	1.39336	1.38484	1.37638	54
36	1.37638	1.36800	1.35968	1.35142	1.34323	1.33511	1.32704	53
37	1.32704	1.31904	1.31110	1.30323	1.29541	1.28764	1.27994	52
38	1.27994	1.27230	1.26471	1.25717	1.24969	1.24227	1.23490	51
39	1.23490	1.22758	1.22031	1.21310	1.20593	1.19882	1.19175	50
40	1.19175	1.18474	1.17777	1.17085	1.16398	1.15715	1.15037	49
41	1.15037	1.14363	1.13694	1.13029	1.12369	1.11713	1.11061	48
42	1.11061	1.10414	1.09770	1.09131	1.08496	1.07864	1.07237	47
43	1.07237	1.06613	1.05994	1.05378	1.04766	1.04158	1.03553	46
44	1.03553	1.02952	1.02355	1.01761	1.01170	1.00583	1.00000	45
	60′	50′	40′	30′ TANGENT	20′	10′	0′	Degrees

NATURAL SECANTS AND COSECANTS

Degrees	SECANT 0′	10′	20′	30′	40′	50′	60′	
0	1.00000	1.00001	1.00002	1.00004	1.00007	1.00011	1.00015	89
1	1.00015	1.00021	1.00027	1.00034	1.00042	1.00051	1.00061	88
2	1.00061	1.00072	1.00083	1.00095	1.00108	1.00122	1.00137	87
3	1.00137	1.00153	1.00169	1.00187	1.00205	1.00224	1.00244	86
4	1.00244	1.00265	1.00287	1.00309	1.00333	1.00357	1.00382	85
5	1.00382	1.00408	1.00435	1.00463	1.00491	1.00521	1.00551	84
6	1.00551	1.00582	1.00614	1.00647	1.00681	1.00715	1.00751	83
7	1.00751	1.00787	1.00825	1.00863	1.00902	1.00942	1.00983	82
8	1.00983	1.01024	1.01067	1.01111	1.01155	1.01200	1.01247	81
9	1.01247	1.01294	1.01342	1.01391	1.01440	1.01491	1.01543	80
10	1.01543	1.01595	1.01649	1.01703	1.01758	1.01815	1.01872	79
11	1.01872	1.00930	1.01989	1.02049	1.02110	1.02171	1.02234	78
12	1.02234	1.02298	1.02362	1.02428	1.02494	1.02562	1.02630	77
13	1.02630	1.02700	1.02770	1.02842	1.02914	1.02987	1.03061	76
14	1.03061	1.03137	1.03213	1.03290	1.03368	1.03447	1.03528	75
15	1.03528	1.03609	1.03691	1.03774	1.03858	1.03944	1.04030	74
16	1.04030	1.04117	1.04206	1.04295	1.04385	1.04477	1.04569	73
17	1.04569	1.04663	1.04757	1.04853	1.04950	1.05047	1.05146	72
18	1.05146	1.05246	1.05347	1.05449	1.05552	1.05657	1.05762	71
19	1.05762	1.05869	1.05976	1.06085	1.06195	1.06306	1.06418	70
20	1.06418	1.06531	1.06645	1.06761	1.06878	1.06995	1.07115	69
21	1.07115	1.07235	1.07356	1.07479	1.07602	1.07727	1.07853	68
22	1.07853	1.07981	1.08109	1.08239	1.08370	1.08503	1.08636	67
23	1.08636	1.08771	1.08907	1.09044	1.09183	1.09323	1.09464	66
24	1.09464	1.09606	1.09750	1.09895	1.10041	1.10189	1.10338	65
25	1.10338	1.10488	1.10640	1.10793	1.10947	1.11103	1.11260	64
26	1.11260	1.11419	1.11579	1.11740	1.11903	1.12067	1.12233	63
27	1.12233	1.12400	1.12568	1.12738	1.12910	1.13083	1.13257	62
28	1.13257	1.13433	1.13610	1.13789	1.13970	1.14152	1.14335	61
29	1.14335	1.14521	1.14707	1.14896	1.15085	1.15277	1.15470	60
30	1.15470	1.15665	1.15861	1.16059	1.16259	1.16460	1.16663	59
31	1.16663	1.16868	1.17075	1.17283	1.17493	1.17704	1.17918	58
32	1.17918	1.18133	1.18350	1.18569	1.18790	1.19012	1.19236	57
33	1.19236	1.19463	1.19691	1.19920	1.20152	1.20386	1.20622	56
34	1.20622	1.20859	1.21099	1.21341	1.21584	1.21830	1.22077	55
35	1.22077	1.22327	1.22579	1.22833	1.23089	1.23347	1.23607	54
36	1.23607	1.23869	1.24134	1.24400	1.24669	1.24940	1.25214	53
37	1.25214	1.25489	1.25767	1.26047	2.26330	1.26615	1.26902	52
38	1.26902	1.27191	1.27483	1.27778	1.28075	1.28374	1.28676	51
39	1.28676	1.28980	1.29287	1.29597	1.29909	1.30223	1.30541	50
40	1.30541	1.30861	1.31183	1.31509	1.31837	1.32168	1.32501	49
41	1.32501	1.32838	1.33177	1.33519	1.33864	1.34212	1.34563	48
42	1.34563	1.34917	1.35274	1.35634	1.35997	1.36363	1.36733	47
43	1.36733	1.37105	1.37481	1.37860	1.38242	1.38628	1.39016	46
44	1.39016	1.39409	1.39804	1.40203	1.40606	1.41012	1.41421	45
	60′	50′	40′	30′	20′	10′	0′ COSECANT	Degrees

NATURAL COSECANTS AND SECANTS

Degrees	COSECANT 0′	10′	20′	30′	40′	50′	60′	
0	∞	343.77516	171.88831	114.59301	85.94561	68.75736	57.29869	89
1	57.29869	49.11406	42.97571	38.20155	34.38232	31.25758	28.65371	88
2	28.65371	26.45051	24.56212	22.92559	21.49368	20.23028	19.10732	87
3	19.10732	18.10262	17.19843	16.38041	15.63679	14.95788	14.33559	86
4	14.33559	13.76312	13.23472	12.74550	12.29125	11.86837	11.47371	85
5	11.47371	11.10455	10.75849	10.43343	10.12752	9.83912	9.56677	84
6	9.56677	9.30917	9.06515	8.83367	8.61379	8.46466	8.20551	83
7	8.20551	8.01565	7.83443	7.66130	0.49571	7.33719	7.18530	82
8	7.18530	7.03962	6.89979	6.76547	6.63633	6.51208	6.39245	81
9	6.39245	6.27719	6.16607	6.05886	5.95536	5.85539	5.75877	80
10	5.75877	5.66533	5.57493	5.48740	5.40263	5.32049	5.24084	79
11	5.24084	5.16359	5.08863	5.01585	4.94517	4.87649	4.80973	78
12	4.80973	4.74482	4.68167	4.62023	4.56041	4.50216	4.44541	77
13	4.44541	4.39012	4.33622	4.28366	4.23239	4.18238	4.13357	76
14	4.13357	4.08591	4.03938	3.99393	3.94952	3.90613	3.86370	75
15	3.86370	3.82223	3.78166	3.74198	3.70315	3.66515	3.62796	74
16	3.62796	3.59154	3.55587	3.52094	3.48671	3.45317	3.42030	73
17	3.42030	3.38808	3.35649	3.32551	3.29512	3.26531	3.23607	72
18	3.23607	3.20737	3.17920	3.15155	3.12440	3.09774	3.07155	71
19	3.07155	3.04584	3.02057	2.99574	2.97135	2.94737	2.92380	70
20	2.92380	2.90063	2.87785	2.85545	2.83342	2.81175	2.79043	69
21	2.79043	2.76945	2.74881	2.72850	2.70851	2.68884	2.66947	68
22	2.66947	2.65040	2.63162	2.61313	2.59491	2.57698	2.55930	67
23	2.55930	2.54190	2.52474	2.50784	2.49119	2.47477	2.45859	66
24	2.45859	2.44264	2.42692	2.41142	2.39614	2.38107	2.36620	65
25	2.36620	2.35154	2.33708	2.32282	2.30875	2.29487	2.28117	64
26	2.28117	2.26766	2.25432	2.24116	2.22817	2.21535	2.20269	63
27	2.20269	2.19019	2.17786	2.16568	2.15366	2.14178	2.13005	62
28	2.13005	2.11847	2.10704	2.09574	2.08458	2.07356	2.06267	61
29	2.06267	2.05191	2.04128	2.0377	2.02039	2.01014	2.00000	60
30	2.00000	1.98998	1.98008	1.97029	1.96062	1.95106	1.94160	59
31	1.94160	1.93226	1.92302	1.91388	1.90485	1.89591	1.88709	58
32	1.88708	1.87834	1.86990	1.86116	1.85271	1.84435	1.83608	57
33	1.83608	1.82790	1.81981	1.81180	1.80388	1.79604	1.78829	56
34	1.78829	1.78062	1.77303	1.76552	1.75808	1.75073	1.74345	55
35	1.74345	1.73624	1.72911	1.72205	1.71506	1.70815	1.70130	54
36	1.70130	1.69452	1.68782	1.68117	1.67460	1.66809	1.66164	53
37	1.66164	1.65526	1.64894	1.64268	1.63648	1.63035	1.62427	52
38	1.62427	1.61825	1.61229	1.60639	1.60054	1.59475	1.58902	51
39	1.58902	1.58333	1.57771	1.57213	1.56661	1.56114	1.55572	50
40	1.55572	1.55036	1.54504	1.53977	1.53455	1.52938	1.52425	49
41	1.52425	1.51918	1.51415	1.50916	1.50422	1.49933	1.49448	48
42	1.49448	1.48967	1.48491	1.48019	1.47551	1.47087	1.46628	47
43	1.46628	1.46173	1.45721	1.45274	1.44831	1.44391	1.43956	46
44	1.43956	1.43524	1.43096	1.42672	1.42251	1.41835	1.41421	45
	60′	50′	40′	30′	20′	10′	0′ SECANT	Degrees

FUNCTIONS OF NUMBERS

.01 – .49

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
.01	.0001	.000001	0.1000	0.2154	$\bar{2}.00000$	100000.000	.03142	.000079
.02	.0004	.000008	0.1414	0.2714	$\bar{2}.30103$	50000.000	.06283	.000314
.03	.0009	.000027	0.1732	0.3107	$\bar{2}.47712$	33333.333	.09425	.000707
.04	.0016	.000064	0.2000	0.3420	$\bar{2}.60206$	25000.000	.12566	.001257
.05	.0025	.000125	0.2236	0.3684	$\bar{2}.69897$	20000.000	.15708	.001964
.06	.0036	.000216	0.2449	0.3915	$\bar{2}.77815$	16666.667	.18850	.002827
.07	.0049	.000343	0.2646	0.4121	$\bar{2}.84510$	14285.714	.21991	.003849
.08	.0064	.000512	0.2828	0.4309	$\bar{2}.90309$	12500.000	.25133	.005027
.09	.0081	.000729	0.3000	0.4481	$\bar{2}.95424$	11111.111	.28274	.006362
.10	.0100	.001000	0.3162	0.4642	$\bar{1}.00000$	10000.000	.31416	.007854
.11	.0121	.001331	0.3317	0.4791	$\bar{1}.04139$	9090.909	.34558	.009503
.12	.0144	.001728	0.3464	0.4932	$\bar{1}.07918$	8333.333	.37699	.011310
.13	.0169	.002197	0.3606	0.5066	$\bar{1}.11394$	7692.308	.40841	.013273
.14	.0196	.002744	0.3742	0.5192	$\bar{1}.14613$	7142.857	.43982	.015394
.15	.0225	.003375	0.3873	0.5313	$\bar{1}.17609$	6666.667	.47124	.017672
.16	.0256	.004096	0.4000	0.5429	$\bar{1}.20412$	6250.000	.50265	.020106
.17	.0289	.004913	0.4123	0.5540	$\bar{1}.23045$	5882.353	.53407	.022698
.18	.0324	.005832	0.4243	0.5646	$\bar{1}.25527$	5555.556	.56549	.025447
.19	.0361	.006859	0.4359	0.5749	$\bar{1}.27875$	5263.158	.59690	.028353
.20	.0400	.008000	0.4472	0.5848	$\bar{1}.30103$	5000.000	.62832	.031416
.21	.0441	.009261	0.4583	0.5944	$\bar{1}.32222$	4761.905	.65973	.034636
.22	.0484	.010648	0.4690	0.6037	$\bar{1}.34242$	4545.455	.69115	.038013
.23	.0529	.012167	0.4796	0.6127	$\bar{1}.36173$	4347.826	.72257	.041548
.24	.0576	.013824	0.4899	0.6214	$\bar{1}.38021$	4166.667	.75398	.045239
.25	.0625	.015625	0.5000	0.6300	$\bar{1}.39794$	4000.000	.78540	.049087
.26	.0676	.017576	0.5099	0.6383	$\bar{1}.41497$	3846.154	.81681	.053093
.27	.0729	.019683	0.5196	0.6463	$\bar{1}.43136$	3703.704	.84823	.057256
.28	.0784	.021952	0.5292	0.6542	$\bar{1}.44716$	3571.429	.87965	.061575
.29	.0841	.024389	0.5385	0.6619	$\bar{1}.46240$	3448.276	.91106	.066052
.30	.0900	.027000	0.5477	0.6694	$\bar{1}.47712$	3333.333	.94248	.070686
.31	.0961	.029791	0.5568	0.6768	$\bar{1}.49136$	3225.807	.97389	.075477
.32	.1024	.032768	0.5657	0.6840	$\bar{1}.50515$	3125.000	1.00531	.080425
.33	.1089	.035937	0.5745	0.6910	$\bar{1}.51851$	3030.303	1.03673	.085530
.34	.1156	.039304	0.5831	0.6980	$\bar{1}.53148$	2941.177	1.06814	.090792
.35	.1225	.042875	0.5916	0.7047	$\bar{1}.54407$	2857.143	1.09956	.096211
.36	.1296	.046656	0.6000	0.7114	$\bar{1}.55630$	2777.778	1.13097	.101788
.37	.1369	.050653	0.6083	0.7179	$\bar{1}.56820$	2702.703	1.16239	.107521
.38	.1444	.054872	0.6164	0.7243	$\bar{1}.57978$	2631.579	1.19381	.113411
.39	.1521	.059319	0.6245	0.7306	$\bar{1}.59106$	2564.103	1.22522	.119459
.40	.1600	.064000	0.6325	0.7368	$\bar{1}.60206$	2500.000	1.2566	.125664
.41	.1681	.068921	0.6403	0.7429	$\bar{1}.61278$	2439.024	1.2881	.132025
.42	.1764	.074088	0.6481	0.7489	$\bar{1}.62325$	2380.952	1.3195	.138544
.43	.1849	.079507	0.6557	0.7548	$\bar{1}.63347$	2325.581	1.3509	.145220
.44	.1936	.085184	0.6633	0.7606	$\bar{1}.64345$	2272.727	1.3823	.152053
.45	.2025	.091125	0.6708	0.7663	$\bar{1}.65321$	2222.222	1.4137	.159043
.46	.2116	.097336	0.6782	0.7719	$\bar{1}.66276$	2173.913	1.4451	.166190
.47	.2209	.103823	0.6856	0.7775	$\bar{1}.67210$	2127.660	1.4765	.173494
.48	.2304	.110592	0.6928	0.7830	$\bar{1}.68124$	2083.333	1.5080	.180956
.49	.2401	.117649	0.7000	0.7884	$\bar{1}.69020$	2040.816	1.5394	.188574

FUNCTIONS OF NUMBERS

1 – 49

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
1	1	1	1.0000	1.0000	0.00000	1000.000	3.142	0.7854
2	4	8	1.4142	1.2599	0.30103	500.000	6.283	3.1416
3	9	27	1.7321	1.4422	0.47712	333.333	9.425	7.0686
4	16	64	2.0000	1.5874	0.60206	250.000	12.566	12.5664
5	25	125	2.2361	1.7100	0.69897	200.000	15.708	19.6350
6	36	216	2.4495	1.8171	0.77815	166.667	18.850	28.2743
7	49	343	2.6458	1.9129	0.84510	142.857	21.991	38.4845
8	64	512	2.8284	2.0000	0.90309	125.000	25.133	50.2655
9	81	729	3.0000	2.0801	0.95424	111.111	28.274	63.6173
10	100	1000	3.1623	2.1544	1.00000	100.000	31.416	78.5398
11	121	1331	3.3166	2.2240	1.04139	90.9091	34.558	95.0332
12	144	1728	3.4641	2.2894	1.07918	83.3333	37.699	113.097
13	169	2197	3.6056	2.3513	1.11394	76.9231	40.841	132.732
14	196	2744	3.7417	2.4101	1.14613	71.4286	43.982	153.938
15	225	3375	3.8730	2.4662	1.17609	66.6667	47.124	176.715
16	256	4096	4.0000	2.5198	1.20412	62.5000	50.265	201.062
17	289	4913	4.1231	2.5713	1.23045	58.8235	53.407	226.980
18	324	5832	4.2426	2.6207	1.25527	55.5556	56.549	254.469
19	361	6859	4.3589	2.6684	1.27875	52.6316	59.690	283.529
20	400	8000	4.4721	2.7144	1.30103	50.0000	62.832	314.159
21	441	9261	4.5826	2.7589	1.32222	47.6190	65.973	346.361
22	484	10648	4.6904	2.8020	1.34242	45.4545	69.115	380.133
23	529	12167	4.7958	2.8439	1.36173	43.4783	72.257	415.476
24	576	13824	4.8990	2.8845	1.38021	41.6667	75.398	452.389
25	625	15625	5.0000	2.9240	1.39794	40.0000	78.540	490.874
26	676	17576	5.0990	2.9625	1.41497	38.4615	81.681	530.929
27	729	19683	5.1962	3.0000	1.43136	37.0370	84.823	572.555
28	784	21952	5.2915	3.0366	1.44716	35.7143	87.965	615.752
29	841	24389	5.3852	3.0723	1.46240	34.4828	91.106	660.520
30	900	27000	5.4772	3.1072	1.47712	33.3333	94.248	706.858
31	961	29791	5.5678	3.1414	1.49136	32.2581	97.389	754.768
32	1024	32768	5.6569	3.1748	1.50515	31.2500	100.531	804.248
33	1089	35937	5.7446	3.2075	1.51851	30.3030	103.673	855.299
34	1156	39304	5.8310	3.2396	1.53148	29.4118	106.814	907.920
35	1225	42875	5.9161	3.2711	1.54407	28.5714	109.956	962.113
36	1296	46656	6.0000	3.3019	1.55630	27.7778	113.097	1017.88
37	1369	50653	6.0828	3.3322	1.56820	27.0270	116.239	1075.21
38	1444	54872	6.1644	3.3620	1.57978	26.3158	119.381	1134.11
39	1521	59319	6.2450	3.3912	1.59106	25.6410	122.522	1194.59
40	1600	64000	6.3246	3.4200	1.60206	25.0000	125.66	1256.64
41	1681	68921	6.4031	3.4482	1.61278	24.3902	128.81	1320.25
42	1764	74088	6.4807	3.4760	1.62325	23.8095	131.95	1385.44
43	1849	79507	6.5574	3.5034	1.63347	23.2558	135.09	1452.20
44	1936	85184	6.6332	3.5303	1.64345	22.7273	138.23	1520.53
45	2025	91125	6.7082	3.5569	1.65321	22.2222	141.37	1590.43
46	2116	97336	6.7823	3.5830	1.66276	21.7391	144.51	1661.90
47	2209	103823	6.8557	3.6088	1.67210	21.2766	147.65	1734.94
48	2304	110592	6.9282	3.6342	1.68124	20.8333	150.80	1809.56
49	2401	117649	7.0000	3.6593	1.69020	20.4082	153.94	1885.74

FUNCTIONS OF NUMBERS

50 – 99

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
.50	.2500	.125000	0.7071	0.7937	$\bar{1}$.69897	2000.000	1.5708	.19635
.51	.2601	.132651	0.7141	0.7990	$\bar{1}$.70757	1960.784	1.6022	.20428
.52	.2704	.140608	0.7211	0.8041	$\bar{1}$.71600	1923.077	1.6336	.21237
.53	.2809	.148877	0.7280	0.8093	$\bar{1}$.72428	1886.793	1.6650	.22062
.54	.2916	.157464	0.7348	0.8143	$\bar{1}$.73239	1851.852	1.6965	.22902
.55	.3025	.166375	0.7416	0.8193	$\bar{1}$.74036	1818.182	1.7279	.23758
.56	.3136	.175616	0.7483	0.8243	$\bar{1}$.74819	1785.714	1.7593	.24630
.57	.3249	.185193	0.7550	0.8291	$\bar{1}$.75587	1754.386	1.7907	.25518
.58	.3364	.195112	0.7616	0.8340	$\bar{1}$.76343	1724.138	1.8221	.26401
.59	.3481	.205379	0.7681	0.8387	$\bar{1}$.77085	1694.915	1.8535	.27340
.60	.3600	.216000	0.7746	0.8434	$\bar{1}$.77815	1666.667	1.8850	.28274
.61	.3721	.226981	0.7810	0.8481	$\bar{1}$.78533	1639.344	1.9164	.29225
.62	.3844	.238328	0.7874	0.8527	$\bar{1}$.79239	1612.903	1.9478	.30191
.63	.3969	.250047	0.7937	0.8573	$\bar{1}$.79934	1587.302	1.9792	.31173
.64	.4096	.262144	0.8000	0.8618	$\bar{1}$.80618	1562.500	2.0106	.32170
.65	.4225	.274625	0.8062	0.8662	$\bar{1}$.81291	1538.462	2.0420	.33183
.66	.4356	.287496	0.8124	0.8707	$\bar{1}$.81954	1515.152	2.0735	.34212
.67	.4489	.300763	0.8185	0.8750	$\bar{1}$.82607	1492.537	2.1049	.35257
.68	.4624	.314432	0.8246	0.8794	$\bar{1}$.83251	1470.588	2.1363	.36317
.69	.4761	.328509	0.8307	0.8837	$\bar{1}$.83885	1449.275	2.1677	.37393
.70	.4900	.343000	0.8367	0.8879	$\bar{1}$.84510	1428.571	2.1991	.38485
.71	.5041	.357911	0.8426	0.8921	$\bar{1}$.85126	1408.451	2.2305	.39592
.72	.5184	.373248	0.8485	0.8963	$\bar{1}$.85733	1388.889	2.2620	.40715
.73	.5329	.389017	0.8544	0.9004	$\bar{1}$.86332	1369.863	2.2934	.41854
.74	.5476	.405224	0.8602	0.9045	$\bar{1}$.86923	1351.351	2.3248	.43008
.75	.5625	.421875	0.8660	0.9086	$\bar{1}$.87506	1333.333	2.3562	.44179
.76	.5776	.438976	0.8718	0.9126	$\bar{1}$.88081	1315.790	2.3876	.45365
.77	.5929	.456533	0.8775	0.9166	$\bar{1}$.88649	1298.701	2.4190	.46566
.78	.6084	.474552	0.8832	0.9205	$\bar{1}$.89209	1282.051	2.4504	.47784
.79	.6241	.493039	0.8888	0.9244	$\bar{1}$.89763	1265.823	2.4819	.49017
.80	.6400	.512000	0.8944	0.9283	$\bar{1}$.90309	1250.000	2.5133	.50266
.81	.6561	.531441	0.9000	0.9322	$\bar{1}$.90849	1234.568	2.5447	.51530
.82	.6724	.551368	0.9055	0.9360	$\bar{1}$.91381	1219.512	2.5761	.52810
.83	.6889	.571787	0.9110	0.9398	$\bar{1}$.91908	1204.819	2.6075	.54106
.84	.7056	.592704	0.9165	0.9435	$\bar{1}$.92428	1190.476	2.6389	.55418
.85	.7225	.614125	0.9220	0.9473	$\bar{1}$.92942	1176.471	2.6704	.56745
.86	.7396	.636056	0.9274	0.9510	$\bar{1}$.93450	1162.791	2.7018	.58088
.87	.7569	.658503	0.9327	0.9546	$\bar{1}$.93952	1149.425	2.7332	.59447
.88	.7744	.681472	0.9381	0.9583	$\bar{1}$.94448	1136.364	2.7646	.60821
.89	.7921	.704969	0.9434	0.9619	$\bar{1}$.94939	1123.596	2.7960	.62211
.90	.8100	.729000	0.9487	0.9655	$\bar{1}$.95424	1111.111	2.8274	.63617
.91	.8281	.753571	0.9539	0.9691	$\bar{1}$.95904	1098.901	2.8589	.65039
.92	.8464	.778688	0.9592	0.9726	$\bar{1}$.96379	1086.957	2.8903	.66476
.93	.8649	.804357	0.9644	0.9761	$\bar{1}$.96848	1075.269	2.9217	.67929
.94	.8836	.830584	0.9695	0.9796	$\bar{1}$.97313	1063.830	2.9531	.69398
.95	.9025	.857375	0.9747	0.9830	$\bar{1}$.97772	1052.632	2.9845	.70882
.96	.9216	.884736	0.9798	0.9865	$\bar{1}$.98227	1041.667	3.0159	.72382
.97	.9409	.912673	0.9849	0.9899	$\bar{1}$.98677	1030.928	3.0473	.73898
.98	.9604	.941192	0.9899	0.9933	$\bar{1}$.99123	1020.408	3.0788	.75430
.99	.9801	.970299	0.9950	0.9967	$\bar{1}$.99564	1010.101	3.1102	.76977

FUNCTIONS OF NUMBERS

50 – 99

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
50	2500	125000	7.0711	3.6840	1.69897	20.0000	157.08	1963.50
51	2601	132651	7.1414	3.7084	1.70757	19.6078	160.22	2042.82
52	2704	140608	7.2111	3.7325	1.71600	19.2308	163.36	2123.72
53	2809	148877	7.2801	3.7563	1.72428	18.8679	166.50	2206.18
54	2916	157464	7.3485	3.7798	1.73239	18.5185	169.65	2290.22
55	3025	166375	7.4162	3.8030	1.74036	18.1818	172.79	2375.83
56	3136	175616	7.4833	3.8259	1.74819	17.8571	175.93	2463.01
57	3249	185193	7.5498	3.8485	1.75587	17.5439	179.07	2551.76
58	3364	195112	7.6158	3.8709	1.76343	17.2414	182.21	2642.08
59	3481	205379	7.6811	3.8930	1.77085	16.9492	185.35	2733.97
60	3600	216000	7.7460	3.9149	1.77815	16.6667	188.50	2827.43
61	3721	226981	7.8102	3.9365	1.78533	16.3934	191.64	2922.47
62	3844	238328	7.8740	3.9579	1.79239	16.1290	194.78	3019.07
63	3969	250047	7.9373	3.9791	1.79934	15.8730	197.92	3117.25
64	4096	262144	8.0000	4.0000	1.80618	15.6250	201.06	3216.99
65	4225	274625	8.0623	4.0207	1.81291	15.3846	204.20	3318.31
66	4356	287496	8.1240	4.0412	1.81954	15.1515	207.35	3421.19
67	4489	300763	8.1854	4.0615	1.82607	14.9254	210.49	3525.65
68	4624	314432	8.2462	4.0817	1.83251	14.7059	213.63	3631.68
69	4761	328509	8.3066	4.1016	1.83885	14.4928	216.77	3739.28
70	4900	343000	8.3666	4.1213	1.84510	14.2857	219.91	3848.45
71	5041	357911	8.4261	4.1408	1.85126	14.0845	223.05	3959.19
72	5184	373248	8.4853	4.1602	1.85733	13.8889	226.19	4071.50
73	5329	389017	8.5440	4.1793	1.86332	13.6986	229.34	4185.39
74	5476	405224	8.6023	4.1983	1.86923	13.5135	232.48	4300.84
75	5625	421875	8.6603	4.2172	1.87506	13.3333	235.62	4417.86
76	5776	438976	8.7178	4.2358	1.88081	13.1579	238.76	4536.46
77	5929	456533	8.7750	4.2543	1.88649	12.9870	241.90	4656.63
78	6084	474552	8.8318	4.2727	1.89209	12.8205	245.04	4778.36
79	6241	493039	8.8882	4.2908	1.89763	12.6582	248.19	4901.67
80	6400	512000	8.9443	4.3089	1.90309	12.5000	251.33	5026.55
81	6561	531441	9.0000	4.3267	1.90849	12.3457	254.47	5153.00
82	6724	551368	9.0554	4.3445	1.91381	12.1951	257.61	5281.02
83	6889	571787	9.1104	4.3621	1.91908	12.0482	260.75	5410.61
84	7056	592704	9.1652	4.3795	1.92428	11.9048	263.89	5541.77
85	7225	614125	9.2195	4.3968	1.92942	11.7647	267.04	5674.50
86	7396	636056	9.2736	4.4140	1.93450	11.6279	270.18	5808.80
87	7569	658503	9.3274	4.4310	1.93952	11.4943	273.32	5944.68
88	7744	681472	9.3808	4.4480	1.94448	11.3636	276.46	6082.12
89	7921	704969	9.4340	4.4647	1.94939	11.2360	279.60	6221.14
90	8100	729000	9.4868	4.4814	1.95424	11.1111	282.74	6361.73
91	8281	753571	9.5394	4.4979	1.95904	10.9890	285.88	6503.88
92	8464	778688	9.5917	4.5144	1.96379	10.8696	289.03	6647.61
93	8649	804357	9.6437	4.5307	1.96848	10.7527	292.17	6792.91
94	8836	830584	9.6954	4.5468	1.97313	10.6383	295.31	6939.78
95	9025	857375	9.7468	4.5629	1.97772	10.5263	298.45	7088.22
96	9216	884736	9.7980	4.5789	1.98227	10.4167	301.59	7238.23
97	9409	912673	9.8489	4.5947	1.98677	10.3093	304.73	7389.81
98	9604	941192	9.8995	4.6104	1.99123	10.2041	307.88	7542.96
99	9801	970299	9.9499	4.6261	1.99564	10.1010	311.02	7697.69

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FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
100	10000	1000000	10.0000	4.6416	2.00000	10.0000	314.16	7853.98
101	10201	1030301	10.0499	4.6570	2.00432	9.90099	317.30	8011.85
102	10404	1061208	10.0995	4.6723	2.00860	9.80392	320.44	8171.28
103	10609	1092727	10.1489	4.6875	2.01284	9.70874	323.58	8332.29
104	10816	1124864	10.1980	4.7027	2.01703	9.61538	326.73	8494.87
105	11025	1157625	10.2470	4.7177	2.02119	9.52381	329.87	8659.01
106	11236	1191016	10.2956	4.7326	2.02531	9.43396	333.01	8824.73
107	11449	1225043	10.3441	4.7475	2.02938	9.34579	336.15	8992.02
108	11664	1259712	10.3923	4.7622	2.03342	9.25926	339.29	9160.88
109	11881	1295029	10.4403	4.7769	2.03743	9.17431	342.43	9331.32
110	12100	1331000	10.4881	4.7914	2.04139	9.09091	345.58	9503.32
111	12321	1367631	10.5357	4.8059	2.04532	9.00901	348.72	9676.89
112	12544	1404928	10.5830	4.8203	2.04922	8.92857	351.86	9852.03
113	12769	1442897	10.6301	4.8346	2.05308	8.84956	355.00	10028.7
114	12996	1481544	10.6771	4.8488	2.05690	8.77193	358.14	10207.0
115	13225	1520875	10.7238	4.8629	2.06070	8.69565	361.28	10386.9
116	13456	1560896	10.7703	4.8770	2.06446	8.62069	364.42	10568.3
117	13689	1601613	10.8167	4.8910	2.06819	8.54701	367.57	10751.3
118	13924	1643032	10.8628	4.9049	2.07188	8.47458	370.71	10935.9
119	14161	1685159	10.9087	4.9187	2.07555	8.40336	373.85	11122.0
120	14400	1728000	10.9545	4.9324	2.07918	8.33333	376.99	11309.7
121	14641	1771561	11.0000	4.9461	2.08279	8.26446	380.13	11499.0
122	14884	1815848	11.0454	4.9597	2.08636	8.19672	383.27	11689.9
123	15129	1860867	11.0905	4.9732	2.08991	8.13008	386.42	11882.3
124	15376	1906624	11.1355	4.9866	2.09342	8.06452	389.56	12076.3
125	15625	1953125	11.1803	5.0000	2.09691	8.00000	392.70	12271.8
126	15876	2000376	11.2250	5.0133	2.10037	7.93651	395.84	12469.0
127	16129	2048383	11.2694	5.0265	2.10380	7.87402	398.98	12667.7
128	16384	2097152	11.3137	5.0397	2.10721	7.81250	402.12	12868.0
129	16641	2146689	11.3578	5.0528	2.11059	7.75194	405.27	13069.8
130	16900	2197000	11.4018	5.0658	2.11394	7.69231	408.41	13273.2
131	17161	2248091	11.4455	5.0788	2.11727	7.63359	411.55	13478.2
132	17424	2299968	11.4891	5.0916	2.12057	7.57576	414.69	13684.8
133	17689	2352637	11.5326	5.1045	2.12385	7.51880	417.83	13892.9
134	17956	2406104	11.5758	5.1172	2.12710	7.46269	420.97	14102.6
135	18225	2460375	11.6190	5.1299	2.13033	7.40741	424.12	14313.9
136	18496	2515456	11.6619	5.1426	2.13354	7.35294	427.26	14526.7
137	18769	2571353	11.7047	5.1551	2.13672	7.29927	430.40	14741.1
138	19044	2628072	11.7473	5.1676	2.13988	7.24638	433.54	14957.1
139	19321	2685619	11.7898	5.1801	2.14301	7.19424	436.68	15174.7
140	19600	2744000	11.8322	5.1925	2.14613	7.14286	439.82	15393.8
141	19881	2803221	11.8743	5.2048	2.14922	7.09220	442.96	15614.5
142	20164	2863288	11.9164	5.2171	2.15229	7.04225	446.11	15836.8
143	20449	2924207	11.9583	5.2293	2.15534	6.99301	449.25	16060.6
144	20736	2985984	12.0000	5.2415	2.15836	6.94444	452.39	16286.0
145	21025	3048625	12.0416	5.2536	2.16137	6.89655	455.53	16513.0
146	21316	3112136	12.0830	5.2656	2.16435	6.84932	458.67	16741.5
147	21609	3176523	12.1244	5.2776	2.16732	6.80272	461.81	16971.7
148	21904	3241792	12.1655	5.2896	2.17026	6.75676	464.96	17203.4
149	22201	3307949	12.2066	5.3015	2.17319	6.71141	468.10	17436.6

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FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
150	22500	3375000	12.2474	5.3133	2.17609	6.66667	471.24	17671.5
151	22801	3442951	12.2882	5.3251	2.17898	6.62252	474.38	17907.9
152	23104	3511808	12.3288	5.3368	2.18184	6.57895	477.52	18145.8
153	23409	3581577	12.3693	5.3485	2.18469	6.53595	480.66	18385.4
154	23716	3652264	12.4097	5.3601	2.18752	6.49351	483.81	18626.5
155	24025	3723875	12.4499	5.3717	2.19033	6.45161	486.95	18869.2
156	24336	3796416	12.4900	5.3832	2.19312	6.41026	490.09	19113.4
157	24649	3869893	12.5300	5.3947	2.19590	6.36943	493.23	19359.3
158	24964	3944312	12.5698	5.4061	2.19866	6.32911	496.37	19606.7
159	25281	4019679	12.6095	5.4175	2.20140	6.28931	499.51	19855.7
160	25600	4096000	12.6491	5.4288	2.20412	6.25000	502.65	20106.2
161	25921	4173281	12.6886	5.4401	2.20683	6.21118	505.80	20358.3
162	26244	4251528	12.7279	5.4514	2.20952	6.17284	508.94	20612.0
163	26569	4330747	12.7671	5.4626	2.21219	6.13497	512.08	20867.2
164	26896	4410944	12.8062	5.4737	2.21484	6.09756	515.22	21124.1
165	27225	4492125	12.8452	5.4848	2.21748	6.06061	518.36	21382.5
166	27556	4574296	12.8841	5.4959	2.22011	6.02410	521.50	21642.4
167	27889	4657463	12.9228	5.5069	2.22272	5.98802	524.65	21904.0
168	28224	4741632	12.9615	5.5178	2.22531	5.95238	527.79	22167.1
169	28561	4826809	13.0000	5.5288	2.22789	5.91716	530.93	22431.8
170	28900	4913000	13.0384	5.5397	2.23045	5.88235	534.07	22698.0
171	29241	5000211	13.0767	5.5505	2.23300	5.84795	537.21	22965.8
172	29584	5088448	13.1149	5.5613	2.23553	5.81395	540.35	23235.2
173	29929	5177717	13.1529	5.5721	2.23805	5.78035	543.50	23506.2
174	30276	5268024	13.1909	5.5828	2.24055	5.74713	546.64	23778.7
175	30625	5359375	13.2288	5.5934	2.24304	5.71429	549.78	24052.8
176	30976	5451776	13.2665	5.6041	2.24551	5.68182	552.92	24328.5
177	31329	5545233	13.3041	5.6147	2.24797	5.64972	556.06	24605.7
178	31684	5639752	13.3417	5.6252	2.25042	5.61798	559.20	24884.6
179	32041	5735339	13.3791	5.6357	2.25285	5.58659	562.35	25164.9
180	32400	5832000	13.4164	5.6462	2.25527	5.55556	565.49	25446.9
181	32761	5929741	13.4536	5.6567	2.25768	5.52486	568.63	25730.4
182	33124	6028568	13.4907	5.6671	2.26007	5.49451	571.77	26015.5
183	33489	6128487	13.5277	5.6774	2.26245	5.46448	574.91	26302.2
184	33856	6229504	13.5647	5.6877	2.26482	5.43478	578.05	26590.4
185	34225	6331625	13.6015	5.6980	2.26717	5.40541	581.19	26880.3
186	34596	6434856	13.6382	5.7083	2.26951	5.37634	584.34	27171.6
187	34969	6539203	13.6748	5.7185	2.27184	5.34759	587.48	27464.6
188	35344	6644672	13.7113	5.7287	2.27416	5.31915	590.62	27759.1
189	35721	6751269	13.7477	5.7388	2.27646	5.29101	593.76	28055.2
190	36100	6859000	13.7840	5.7489	2.27875	5.26316	596.90	28352.9
191	36481	6967871	13.8203	5.7590	2.28103	5.23560	600.04	28652.1
192	36864	7077888	13.8564	5.7690	2.28330	5.20833	603.19	28952.9
193	37249	7189057	13.8924	5.7790	2.28556	5.18135	606.33	29255.3
194	37636	7301384	13.9284	5.7890	2.28780	5.15464	609.47	29559.2
195	38025	7414875	13.9642	5.7989	2.29003	5.12821	612.61	29864.8
196	38416	7529536	14.0000	5.8088	2.29226	5.10204	615.75	30171.9
197	38809	7645373	14.0357	5.8186	2.29447	5.07614	618.89	30480.5
198	39204	7762392	14.0712	5.8285	2.29667	5.05051	622.04	30790.7
199	39601	7880599	14.1067	5.8383	2.29885	5.02513	625.18	31102.6

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FUNCTIONS OF NUMBERS

No	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
200	40000	8000000	14.1421	5.8480	2.30103	5.00000	628.32	31415.9
201	40401	8120601	14.1774	5.8578	2.30320	4.97512	631.46	31730.9
202	40804	8242408	14.2127	5.8675	2.30535	4.95050	634.60	32047.4
203	41209	8365427	14.2478	5.8771	2.30750	4.92611	637.74	32365.5
204	41616	8489664	14.2829	5.8868	2.30963	4.90196	640.88	32685.1
205	42025	8615125	14.3178	5.8964	2.31175	4.87805	644.03	33006.4
206	42436	8741816	14.3527	5.9059	2.31387	4.85437	647.17	33329.2
207	42849	8869743	14.3875	5.9155	2.31597	4.83092	650.31	33653.5
208	43264	8998912	14.4222	5.9250	2.31806	4.80769	653.45	33979.5
209	43681	9129329	14.4568	5.9345	2.32015	4.78469	656.59	34307.0
210	44100	9261000	14.4914	5.9439	2.32222	4.76190	659.73	34636.1
211	44521	9393931	14.5258	5.9533	2.32428	4.73934	662.88	34966.7
212	44944	9528128	14.5602	5.9627	2.32634	4.71698	666.02	35298.9
213	45369	9663597	14.5945	5.9721	2.32838	4.69484	669.16	35632.7
214	45796	9800344	14.6287	5.9814	2.33041	4.67290	672.30	35968.1
215	46225	9938375	14.6629	5.9907	2.33244	4.65116	675.44	36305.0
216	46656	10077696	14.6969	6.0000	2.33445	4.62963	678.58	36643.5
217	47089	10218313	14.7309	6.0092	2.33646	4.60829	681.73	36983.6
218	47524	10360232	14.7648	6.0185	2.33846	4.58716	684.87	37325.3
219	47961	10503459	14.7986	6.0277	2.34044	4.56621	688.01	37668.5
220	48400	10648000	14.8324	6.0368	2.34242	4.54545	691.15	38013.3
221	48841	10793861	14.8661	6.0459	2.34439	4.52489	694.29	38359.6
222	49284	10941048	14.8997	6.0550	2.34635	4.50450	697.43	38707.6
223	49729	11089567	14.9332	6.0641	2.34830	4.48430	700.58	39057.1
224	50176	11239424	14.9666	6.0732	2.35025	4.46429	703.72	39408.1
225	50625	11390625	15.0000	6.0822	2.35218	4.44444	706.86	39760.8
226	51076	11543176	15.0333	6.0912	2.35411	4.42478	710.00	40115.0
227	51529	11697083	15.0665	6.1002	2.35603	4.40529	713.14	40470.8
228	51984	11852352	15.0997	6.1091	2.35793	4.38596	716.28	40828.1
229	52441	12008989	15.1327	6.1180	2.35984	4.36681	719.42	41187.1
230	52900	12167000	15.1658	6.1269	2.36173	4.34783	722.57	41547.6
231	53361	12326391	15.1987	6.1358	2.36361	4.32900	725.71	41909.6
232	53824	12487168	15.2315	6.1446	2.36549	4.31034	728.85	42273.3
233	54289	12649337	15.2643	6.1534	2.36736	4.29185	731.99	42638.5
234	54756	12812904	15.2971	6.1622	2.36922	4.27350	735.13	43005.3
235	55225	12977875	15.3297	6.1710	2.37107	4.25532	738.27	43373.6
236	55696	13144256	15.3623	6.1797	2.37291	4.23729	741.42	43743.5
237	56169	13312053	15.3948	6.1885	2.37475	4.21941	744.56	44115.0
238	56644	13481272	15.4272	6.1972	2.37658	4.20168	747.70	44488.1
239	57121	13651919	15.4596	6.2058	2.37840	4.18410	750.84	44862.7
240	57600	13824000	15.4919	6.2145	2.38021	4.16667	753.98	45238.9
241	58081	13997521	15.5242	6.2231	2.38202	4.14938	757.12	45616.7
242	58564	14172488	15.5563	6.2317	2.38382	4.13223	760.27	45996.1
243	59049	14348907	15.5885	6.2403	2.38561	4.11523	763.41	46377.0
244	59536	14526784	15.6205	6.2488	2.38739	4.09836	766.55	46759.5
245	60025	14706125	15.6525	6.2573	2.38917	4.08163	769.69	47143.5
246	60516	14886936	15.6844	6.2658	2.39094	4.06504	772.83	47529.2
247	61009	15069223	15.7162	6.2743	2.39270	4.04858	775.97	47916.4
248	61504	15252992	15.7480	6.2828	2.39445	4.03226	779.12	48305.1
249	62001	15438249	15.7797	6.2912	2.39620	4.01606	782.26	48695.5

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FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
250	62500	15625000	15.8114	6.2996	2.39794	4.00000	785.40	49087.4
251	63001	15813251	15.8430	6.3080	2.39967	3.98406	788.54	49480.9
252	63504	16003008	15.8745	6.3164	2.40140	3.96825	791.68	49875.9
253	64009	16194277	15.9060	6.3247	2.40312	3.95257	794.82	50272.6
254	64516	16387064	15.9374	6.3330	2.40483	3.93701	797.96	50670.7
255	65025	16581375	15.9687	6.3413	2.40654	3.92157	801.11	51070.5
256	65536	16777216	16.0000	6.3496	2.40824	3.90625	804.25	51471.9
257	66049	16974593	16.0312	6.3579	2.40993	3.89105	807.39	51874.8
258	66564	17173512	16.0624	6.3661	2.41162	3.87597	810.53	52279.2
259	67081	17373979	16.0935	6.3743	2.41330	3.86100	813.67	52685.3
260	67600	17576000	16.1245	6.3825	2.41497	3.84615	816.81	53092.9
261	68121	17779581	16.1555	6.3907	2.41664	3.83142	819.96	53502.1
262	68644	17984728	16.1864	6.3988	2.41830	3.81679	823.10	53912.9
263	69169	18191447	16.2173	6.4070	2.41996	3.80228	826.24	54325.2
264	69696	18399744	16.2481	6.4151	2.42160	3.78788	829.38	54739.1
265	70225	18609625	16.2788	6.4232	2.42325	3.77358	832.52	55154.6
266	70756	18821096	16.3095	6.4312	2.42488	3.75940	835.66	55571.6
267	71289	19034163	16.3401	6.4393	2.42651	3.74532	838.81	55990.2
268	71824	19248832	16.3707	6.4473	2.42813	3.73134	841.95	56410.4
269	72361	19465109	16.4012	6.4553	2.42975	3.71747	845.09	56832.2
270	72900	19683000	16.4317	6.4633	2.43136	3.70370	848.23	57255.5
271	73441	19902511	16.4621	6.4713	2.43297	3.69004	851.37	57680.4
272	73984	20123648	16.4924	6.4792	2.43457	3.67647	854.51	58106.9
273	74529	20346417	16.5227	6.4872	2.43616	3.66300	857.65	58534.9
274	75076	20570824	16.5529	6.4951	2.43775	3.64964	860.80	58964.6
275	75625	20796875	16.5831	6.5030	2.43933	3.63636	863.94	59395.7
276	76176	21024576	16.6132	6.5108	2.44091	3.62319	867.08	59828.5
277	76729	21253933	16.6433	6.5187	2.44248	3.61011	870.22	60262.8
278	77284	21484952	16.6733	6.5265	2.44404	3.59712	873.36	60698.7
279	77841	21717639	16.7033	6.5343	2.44560	3.58423	876.50	61136.2
280	78400	21952000	16.7332	6.5421	2.44716	3.57143	879.65	61575.2
281	78961	22188041	16.7631	6.5499	2.44871	3.55872	882.79	62015.8
282	79524	22425768	16.7929	6.5577	2.45025	3.54610	885.93	62458.0
283	80089	22665187	16.8226	6.5654	2.45179	3.53357	889.07	62901.8
284	80656	22906304	16.8523	6.5731	2.45332	3.52113	892.21	63347.1
285	81225	23149125	16.8819	6.5808	2.45484	3.50877	895.35	63794.0
286	81796	23393656	16.9115	6.5885	2.45637	3.49650	898.50	64242.4
287	82369	23639903	16.9411	6.5962	2.45788	3.48432	901.64	64692.5
288	82944	23887872	16.9706	6.6039	2.45939	3.47222	904.78	65144.1
289	83521	24137569	17.0000	6.6115	2.46090	3.46021	907.92	65597.2
290	84100	24389000	17.0294	6.6191	2.46240	3.44828	911.06	66052.0
291	84681	24642171	17.0587	6.6267	2.46389	3.43643	914.20	66508.3
292	85264	24897088	17.0880	6.6343	2.46538	3.42466	917.35	66966.2
293	85849	25153757	17.1172	6.6419	2.46687	3.41297	920.49	67425.6
294	86436	25412184	17.1464	6.6494	2.46835	3.40136	923.63	67886.7
295	87025	25672375	17.1756	6.6569	2.46982	3.38983	926.77	68349.3
296	87616	25934336	17.2047	6.6644	2.47129	3.37838	929.91	68813.4
297	88209	26198073	17.2337	6.6719	2.47276	3.36700	933.05	69279.2
298	88804	26463592	17.2627	6.6794	2.47422	3.35570	936.19	69746.5
299	89401	26730899	17.2916	6.6869	2.47567	3.34448	939.34	70215.4

FUNCTIONS OF NUMBERS 300–349

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
300	90000	27000000	17.3205	6.6943	2.47712	3.33333	942.48	70685.8
301	90601	27270901	17.3494	6.7018	2.47857	3.32226	945.62	71157.9
302	91204	27543608	17.3781	6.7092	2.48001	3.31126	948.76	71631.5
303	91809	27818127	17.4069	6.7166	2.48144	3.30033	951.90	72106.6
304	92416	28094464	17.4356	6.7240	2.48287	3.28947	955.04	72583.4
305	93025	28372625	17.4642	6.7313	2.48430	3.27869	958.19	73061.7
306	93636	28652616	17.4929	6.7387	2.48572	3.26797	961.33	73541.5
307	94249	28934443	17.5214	6.7460	2.48714	3.25733	964.47	74023.0
308	94864	29218112	17.5499	6.7533	2.48855	3.24675	967.61	74506.0
309	95481	29503629	17.5784	6.7606	2.48996	3.23625	970.75	74990.6
310	96100	29791000	17.6068	6.7679	2.49136	3.22581	973.89	75476.8
311	96721	30080231	17.6352	6.7752	2.49276	3.21543	977.04	75964.5
312	97344	30371328	17.6635	6.7824	2.49415	3.20513	980.18	76453.8
313	97969	30664297	17.6918	6.7897	2.49554	3.19489	983.32	76944.7
314	98596	30959144	17.7200	6.7969	2.49693	3.18471	986.46	77437.1
315	99225	31255875	17.7482	6.8041	2.49831	3.17460	989.60	77931.1
316	99856	31554496	17.7764	6.8113	2.49969	3.16456	992.74	78426.7
317	100489	31855013	17.8045	6.8185	2.50106	3.15457	995.88	78923.9
318	101124	32157432	17.8326	6.8256	2.50243	3.14465	999.03	79422.6
319	101761	32461759	17.8606	6.8328	2.50379	3.13480	1002.2	79922.9
320	102400	32768000	17.8885	6.8399	2.50515	3.12500	1005.3	80424.8
321	103041	33076161	17.9165	6.8470	2.50651	3.11526	1008.5	80928.2
322	103684	33386248	17.9444	6.8541	2.50786	3.10559	1011.6	81433.2
323	104329	33698267	17.9722	6.8612	2.50920	3.09598	1014.7	81939.8
324	104976	34012224	18.0000	6.8683	2.51055	3.08642	1017.9	82448.0
325	105625	34328125	18.0278	6.8753	2.51188	3.07692	1021.0	82957.7
326	106276	34645976	18.0555	6.8824	2.51322	3.06749	1024.2	83469.0
327	106929	34965783	18.0831	6.8894	2.51455	3.05810	1027.3	83981.8
328	107584	35287552	18.1108	6.8964	2.51587	3.04878	1030.4	84496.3
329	108241	35611289	18.1384	6.9034	2.51720	3.03951	1033.6	85012.3
330	108900	35937000	18.1659	6.9104	2.51851	3.03030	1036.7	85529.9
331	109561	36264691	18.1934	6.9174	2.51983	3.02115	1039.9	86049.0
332	110224	36594368	18.2209	6.9244	2.52114	3.01205	1043.0	86569.7
333	110889	36926037	18.2483	6.9313	2.52244	3.00300	1046.2	87092.0
334	111556	37259704	18.2757	6.9382	2.52375	2.99401	1049.3	87615.9
335	112225	37595375	18.3030	6.9451	2.52504	2.98507	1052.4	88141.3
336	112896	37933056	18.3303	6.9521	2.52634	2.97619	1055.6	88668.3
337	113569	38272753	18.3576	6.9589	2.52763	2.96736	1058.7	89196.9
338	114244	38614472	18.3848	6.9658	2.52892	2.95858	1061.9	89727.0
339	114921	38958219	18.4120	6.9727	2.53020	2.94985	1065.0	90258.7
340	115600	39304000	18.4391	6.9795	2.53148	2.94118	1068.1	90792.0
341	116281	39651821	18.4662	6.9864	2.53275	2.93255	1071.3	91326.9
342	116964	40001688	18.4932	6.9932	2.53403	2.92398	1074.4	91863.3
343	117649	40353607	18.5203	7.0000	2.53529	2.91545	1077.6	92401.3
344	118336	40707584	18.5472	7.0068	2.53656	2.90698	1080.7	92940.9
345	119025	41063625	18.5742	7.0136	2.53782	2.89855	1083.8	93482.0
346	119716	41421736	18.6011	7.0203	2.53908	2.89017	1087.0	94024.7
347	120409	41781923	18.6279	7.0271	2.54033	2.88184	1090.1	94569.0
348	121104	42144192	18.6548	7.0338	2.54158	2.87356	1093.3	95114.9
349	121801	42508549	18.6815	7.0406	2.54283	2.86533	1096.4	95662.3

FUNCTIONS OF NUMBERS 350–399

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
350	122500	42875000	18.7083	7.0473	2.54407	2.85714	1099.6	96211.3
351	123201	43243551	18.7350	7.0540	2.54531	2.84900	1102.7	96761.8
352	123904	43614208	18.7617	7.0607	2.54654	2.84091	1105.8	97314.0
353	124609	43986977	18.7883	7.0674	2.54777	2.83286	1109.0	97867.7
354	125316	44361864	18.8149	7.0740	2.54900	2.82486	1112.1	98423.0
355	126025	44738875	18.8414	7.0807	2.55023	2.81690	1115.3	98979.8
356	126736	45118016	18.8680	7.0873	2.55145	2.80899	1118.4	99538.2
357	127449	45499293	18.8944	7.0940	2.55267	2.80112	1121.5	100098
358	128164	45882712	18.9209	7.1006	2.55388	2.79330	1124.7	100660
359	128881	46268279	18.9473	7.1072	2.55509	2.78552	1127.8	101223
360	129600	46656000	18.9737	7.1138	2.55630	2.77778	1131.0	101788
361	130321	47045881	19.0000	7.1204	2.55751	2.77008	1134.1	102354
362	131044	47437928	19.0263	7.1269	2.55871	2.76243	1137.3	102922
363	131769	47832147	19.0526	7.1335	2.55991	2.75482	1140.4	103491
364	132496	48228544	19.0788	7.1400	2.56110	2.74725	1143.5	104062
365	133225	48627125	19.1050	7.1466	2.56229	2.73973	1146.7	104635
366	133956	49027896	19.1311	7.1531	2.56348	2.73224	1149.8	105209
367	134689	49430863	19.1572	7.1596	2.56467	2.72480	1153.0	105785
368	135424	49836032	19.1833	7.1661	2.56585	2.71739	1156.1	106362
369	136161	50243409	19.2094	7.1726	2.56703	2.71003	1159.2	106941
370	136900	50653000	19.2354	7.1791	2.56820	2.70270	1162.4	107521
371	137641	51064811	19.2614	7.1855	2.56937	2.69542	1165.5	108103
372	138384	51478848	19.2873	7.1920	2.57054	2.68817	1168.7	108687
373	139129	51895117	19.3132	7.1984	2.57171	2.68097	1171.8	109272
374	139876	52313624	19.3391	7.2048	2.57287	2.67380	1175.0	109858
375	140625	52734375	19.3649	7.2112	2.57403	2.66667	1178.1	110447
376	141376	53157376	19.3907	7.2177	2.57519	2.65957	1181.2	111036
377	142129	53582633	19.4165	7.2240	2.57634	2.65252	1184.4	111628
378	142884	54010152	19.4422	7.2304	2.57749	2.64550	1187.5	112221
379	143641	54439939	19.4679	7.2368	2.57864	2.63852	1190.7	112815
380	144400	54872000	19.4936	7.2432	2.57978	2.63158	1193.8	113411
381	145161	55306341	19.5192	7.2495	2.58093	2.62467	1196.9	114009
382	145924	55742968	19.5448	7.2558	2.58206	2.61780	1200.1	114608
383	146689	56181887	19.5704	7.2622	2.58320	2.61097	1203.2	115209
384	147456	56623104	19.5959	7.2685	2.58433	2.60417	1206.4	115812
385	148225	57066625	19.6214	7.2748	2.58546	2.59740	1209.5	116416
386	148996	57512456	19.6469	7.2811	2.58659	2.59067	1212.7	117021
387	149769	57960603	19.6723	7.2874	2.58771	2.58398	1215.8	117628
388	150544	58411072	19.6977	7.2936	2.58883	2.57732	1218.9	118237
389	151321	58863869	19.7231	7.2999	2.58995	2.57069	1222.1	118847
390	152100	59319000	19.7484	7.3061	2.59106	2.56410	1225.2	119459
391	152881	59776471	19.7737	7.3124	2.59218	2.55754	1228.4	120072
392	153664	60236288	19.7990	7.3186	2.59329	2.55102	1231.5	120687
393	154449	60698457	19.8242	7.3248	2.59439	2.54453	1234.6	121304
394	155236	61162984	19.8494	7.3310	2.59550	2.53807	1237.8	121922
395	156025	61629875	19.8746	7.3372	2.59660	2.53165	1240.9	122542
396	156816	62099136	19.8997	7.3434	2.59770	2.52525	1244.1	123163
397	157609	62570773	19.9249	7.3496	2.59879	2.51889	1247.2	123786
398	158404	63044792	19.9499	7.3558	2.59988	2.51256	1250.4	124410
399	159201	63521199	19.9750	7.3619	2.60097	2.50627	1253.5	125036

FUNCTIONS OF NUMBERS 400–449

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
400	160000	64000000	20.0000	7.3681	2.60206	2.50000	1256.6	125664
401	160801	64481201	20.0250	7.3742	2.60314	2.49377	1259.8	126293
402	161604	64964808	20.0499	7.3803	2.60423	2.48756	1262.9	126923
403	162409	65450827	20.0749	7.3864	2.60531	2.48139	1266.1	127556
404	163216	65939264	20.0998	7.3925	2.60638	2.47525	1269.2	128190
405	164025	66430125	20.1246	7.3986	2.60746	2.46914	1272.3	128825
406	164836	66923416	20.1494	7.4047	2.60853	2.46305	1275.5	129462
407	165649	67419143	20.1742	7.4108	2.60959	2.45700	1278.6	130100
408	166464	67917312	20.1990	7.4169	2.61066	2.45098	1281.8	130741
409	167281	68417929	20.2237	7.4229	2.61172	2.44499	1284.9	131382
410	168100	68921000	20.2485	7.4290	2.61278	2.43902	1288.1	132025
411	168921	69426531	20.2731	7.4350	2.61384	2.43309	1291.2	132670
412	169744	69934528	20.2978	7.4410	2.61490	2.42718	1294.3	133317
413	170569	70444997	20.3224	7.4470	2.61595	2.42131	1297.5	133965
414	171396	70957944	20.3470	7.4530	2.61700	2.41546	1300.6	134614
415	172225	71473375	20.3715	7.4590	2.61805	2.40964	1303.8	135265
416	173056	71991296	20.3961	7.4650	2.61909	2.40385	1306.9	135918
417	173889	72511713	20.4206	7.4710	2.62014	2.39808	1310.0	136572
418	174724	73034632	20.4450	7.4770	2.62118	2.39234	1313.2	137228
419	175561	73560059	20.4695	7.4829	2.62221	2.38663	1316.3	137885
420	176400	74088000	20.4939	7.4889	2.62325	2.38095	1319.5	138544
421	177241	74618461	20.5183	7.4948	2.62428	2.37530	1322.6	139205
422	178084	75151448	20.5426	7.5007	2.62531	2.36967	1325.8	139867
423	178929	75686967	20.5670	7.5067	2.62634	2.36407	1328.9	140531
424	179776	76225024	20.5913	7.5126	2.62737	2.35849	1332.0	141196
425	180625	76765625	20.6155	7.5185	2.62839	2.35294	1335.2	141863
426	181476	77308776	20.6398	7.5244	2.62941	2.34742	1338.3	142531
427	182329	77854483	20.6640	7.5302	2.63043	2.34192	1341.5	143201
428	183184	78402752	20.6882	7.5361	2.63144	2.33645	1344.6	143872
429	184041	78953589	20.7123	7.5420	2.63246	2.33100	1347.7	144545
430	184900	79507000	20.7364	7.5478	2.63347	2.32558	1350.9	145220
431	185761	80062991	20.7605	7.5537	2.63448	2.32019	1354.0	145896
432	186624	80621568	20.7846	7.5595	2.63548	2.31481	1357.2	146574
433	187489	81182737	20.8087	7.5654	2.63649	2.30947	1360.3	147254
434	188356	81746504	20.8327	7.5712	2.63749	2.30415	1363.5	147934
435	189225	82312875	20.8567	7.5770	2.63849	2.29885	1366.6	148617
436	190096	82881856	20.8806	7.5828	2.63949	2.29358	1369.7	149301
437	190969	83453453	20.9045	7.5886	2.64048	2.28833	1372.9	149987
438	191844	84027672	20.9284	7.5944	2.64147	2.28311	1376.0	150674
439	192721	84604519	20.9523	7.6001	2.64246	2.27790	1379.2	151363
440	193600	85184000	20.9762	7.6059	2.64345	2.27273	1382.3	152053
441	194481	85766121	21.0000	7.6117	2.64444	2.26757	1385.4	152745
442	195364	86350888	21.0238	7.6174	2.64542	2.26244	1388.6	153439
443	196249	86938307	21.0476	7.6232	2.64640	2.25734	1391.7	154134
444	197136	87528384	21.0713	7.6289	2.64738	2.25225	1394.9	154830
445	198025	88121125	21.0950	7.6346	2.64836	2.24719	1398.0	155528
446	198916	88716536	21.1187	7.6403	2.64933	2.24215	1401.2	156228
447	199809	89314623	21.1424	7.6460	2.65031	2.23714	1404.3	156930
448	200704	89915392	21.1660	7.6517	2.65128	2.23214	1407.4	157633
449	201601	90518849	21.1896	7.6574	2.65225	2.22717	1410.6	158337

FUNCTIONS OF NUMBERS 450–499

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
450	202500	91125000	21.2132	7.6631	2.65321	2.22222	1413.7	159043
451	203401	91733851	21.2368	7.6688	2.65418	2.21729	1416.9	159751
452	204304	92345408	21.2603	7.6744	2.65514	2.21239	1420.0	160460
453	205209	92959677	21.2838	7.6801	2.65610	2.20751	1423.1	161171
454	206116	93576664	21.3073	7.6857	2.65706	2.20264	1426.3	161883
455	207025	94196375	21.3307	7.6914	2.65801	2.19780	1429.4	162597
456	207936	94818816	21.3542	7.6970	2.65896	2.19298	1432.6	163313
457	208849	95443993	21.3776	7.7026	2.65992	2.18818	1435.7	164030
458	209764	96071912	21.4009	7.7082	2.66087	2.18341	1438.8	164748
459	210681	96702579	21.4243	7.7138	2.66181	2.17865	1442.0	165468
460	211600	97336000	21.4476	7.7194	2.66276	2.17391	1445.1	166190
461	212521	97972181	21.4709	7.7250	2.66370	2.16920	1448.3	166914
462	213444	98611128	21.4942	7.7306	2.66464	2.16450	1451.4	167639
463	214369	99252847	21.5174	7.7362	2.66558	2.15983	1454.6	168365
464	215296	99897344	21.5407	7.7418	2.66652	2.15517	1457.7	169093
465	216225	100544625	21.5639	7.7473	2.66745	2.15054	1460.8	169823
466	217156	101194696	21.5870	7.7529	2.66839	2.14592	1464.0	170554
467	218089	101847563	21.6102	7.7584	2.66932	2.14133	1467.1	171287
468	219024	102503232	21.6333	7.7639	2.67025	2.13675	1470.3	172021
469	219961	103161709	21.6564	7.7695	2.67117	2.13220	1473.4	172757
470	220900	103823000	21.6795	7.7750	2.67210	2.12766	1476.5	173494
471	221841	104487111	21.7025	7.7805	2.67302	2.12314	1479.7	174234
472	222784	105154048	21.7256	7.7860	2.67394	2.11864	1482.8	174974
473	223729	105823817	21.7486	7.7915	2.67486	2.11416	1486.0	175716
474	224676	106496424	21.7715	7.7970	2.67578	2.10970	1489.1	176460
475	225625	107171875	21.7945	7.8025	2.67669	2.10526	1492.3	177205
476	226576	107850176	21.8174	7.8079	2.67761	2.10084	1495.4	177952
477	227529	108531333	21.8403	7.8134	2.67852	2.09644	1498.5	178701
478	228484	109215352	21.8632	7.8188	2.67943	2.09205	1501.7	179451
479	229441	109902239	21.8861	7.8243	2.68034	2.08768	1504.8	180203
480	230400	110592000	21.9089	7.8297	2.68124	2.08333	1508.0	180956
481	231361	111284641	21.9317	7.8352	2.68215	2.07900	1511.1	181711
482	232324	111980168	21.9545	7.8406	2.68305	2.07469	1514.2	182467
483	233289	112678587	21.9773	7.8460	2.68395	2.07039	1517.4	183225
484	234256	113379904	22.0000	7.8514	2.68485	2.06612	1520.5	183984
485	235225	114084125	22.0227	7.8568	2.68574	2.06186	1523.7	184745
486	236196	114791256	22.0454	7.8622	2.68664	2.05761	1526.8	185508
487	237169	115501303	22.0681	7.8676	2.68753	2.05339	1530.0	186272
488	238144	116214272	22.0907	7.8730	2.68842	2.04918	1533.1	187038
489	239121	116930169	22.1133	7.8784	2.68931	2.04499	1536.2	187805
490	240100	117649000	22.1359	7.8837	2.69020	2.04082	1539.4	188574
491	241081	118370771	22.1585	7.8891	2.69108	2.03666	1542.5	189345
492	242064	119095488	22.1811	7.8944	2.69197	2.03252	1545.7	190117
493	243049	119823157	22.2036	7.8998	2.69285	2.02840	1548.8	190890
494	244036	120553784	22.2261	7.9051	2.69373	2.02429	1551.9	191665
495	245025	121287375	22.2486	7.9105	2.69461	2.02020	1555.1	192442
496	246016	122023936	22.2711	7.9158	2.69548	2.01613	1558.2	193221
497	247009	122763473	22.2935	7.9211	2.69636	2.01207	1561.4	194000
498	248004	123505992	22.3159	7.9264	2.69723	2.00803	1564.5	194782
499	249001	124251499	22.3383	7.9317	2 69810	2.00401	1567.7	195565

500
549

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
500	250000	125000000	22.3607	7.9370	2.69897	2.00000	1570.8	196350
501	251001	125751501	22.3830	7.9423	2.69984	1.99601	1573.9	197136
502	252004	126506008	22.4054	7.9476	2.70070	1.99203	1577.1	197923
503	253009	127263527	22.4277	7.9528	2.70157	1.98807	1580.2	198713
504	254016	128024064	22.4499	7.9581	2.70243	1.98413	1583.4	199504
505	255025	128787625	22.4722	7.9634	2.70329	1.98020	1586.5	200296
506	256036	129554216	22.4944	7.9686	2.70415	1.97628	1589.6	201090
507	257049	130323843	22.5167	7.9739	2.70501	1.97239	1592.8	201886
508	258064	131096512	22.5389	7.9791	2.70586	1.96850	1595.9	202683
509	259081	131872229	22.5610	7.9843	2.70672	1.96464	1599.1	203482
510	260100	132651000	22.5832	7.9896	2.70757	1.96078	1602.2	204282
511	261121	133432831	22.6053	7.9948	2.70842	1.95695	1605.4	205084
512	262144	134217728	22.6274	8.0000	2.70927	1.95312	1608.5	205887
513	263169	135005697	22.6495	8.0052	2.71012	1.94932	1611.6	206692
514	264196	135796744	22.6716	8.0104	2.71096	1.94553	1614.8	207499
515	265225	136590875	22.6936	8.0156	2.71181	1.94175	1617.9	208307
516	266256	137388096	22.7156	8.0208	2.71265	1.93798	1621.1	209117
517	267289	138188413	22.7376	8.0260	2.71349	1.93424	1624.2	209928
518	268324	138991832	22.7596	8.0311	2.71433	1.93050	1627.3	210741
519	269361	139798359	22.7816	8.0363	2.71517	1.92678	1630.5	211556
520	270400	140608000	22.8035	8.0415	2.71600	1.92308	1633.6	212372
521	271441	141420761	22.8254	8.0466	2.71684	1.91939	1636.8	213189
522	272484	142236648	22.8473	8.0517	2.71767	1.91571	1639.9	214008
523	273529	143055667	22.8692	8.0569	2.71850	1.91205	1643.1	214829
524	274576	143877824	22.8910	8.0620	2.71933	1.90840	1646.2	215651
525	275625	144703125	22.9129	8.0671	2.72016	1.90476	1649.3	216475
526	276676	145531576	22.9347	8.0723	2.72099	1.90114	1652.5	217301
527	277729	146363183	22.9565	8.0774	2.72181	1.89753	1655.6	218128
528	278784	147197952	22.9783	8.0825	2.72263	1.89394	1658.8	218956
529	279841	148035889	23.0000	8.0876	2.72346	1.89036	1661.9	219787
530	280900	148877000	23.0217	8.0927	2.72428	1.88679	1665.0	220618
531	281961	149721291	23.0434	8.0978	2.72509	1.88324	1668.2	221452
532	283024	150568768	23.0651	8.1028	2.72591	1.87970	1671.3	222287
533	284089	151419437	23.0868	8.1079	2.72673	1.87617	1674.5	223123
534	285156	152273304	23.1084	8.1130	2.72754	1.87266	1677.6	223961
535	286225	153130375	23.1301	8.1180	2.72835	1.86916	1680.8	224801
536	287296	153990656	23.1517	8.1231	2.72916	1.86567	1683.9	225642
537	288369	154854153	23.1733	8.1281	2.72997	1.86220	1687.0	226484
538	289444	155720872	23.1948	8.1332	2.73078	1.85874	1690.2	227329
539	290521	156590819	23.2164	8.1382	2.73159	1.85529	1693.3	228175
540	291600	157464000	23.2379	8.1433	2.73239	1.85185	1696.5	229022
541	292681	158340421	23.2594	8.1483	2.73320	1.84843	1699.6	229871
542	293764	159220088	23.2809	8.1533	2.73400	1.84502	1702.7	230722
543	294849	160103007	23.3024	8.1583	2.73480	1.84162	1705.9	231574
544	295936	160989184	23.3238	8.1633	2.73560	1.83824	1709.0	232428
545	297025	161878625	23.3452	8.1683	2.73640	1.83486	1712.2	233283
546	298116	162771336	23.3666	8.1733	2.73719	1.83150	1715.3	234140
547	299209	163667323	23.3880	8.1783	2.73799	1.82815	1718.5	234998
548	300304	164566592	23.4094	8.1833	2.73878	1.82482	1721.6	235858
549	301401	165469149	23.4307	8.1882	2.73957	1.82149	1724.7	236720

550
599

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
550	302500	166375000	23.4521	8.1932	2.74036	1.81818	1727.9	237583
551	303601	167284151	23.4734	8.1982	2.74115	1.81488	1731.0	238448
552	304704	168196608	23.4947	8.2031	2.74194	1.81159	1734.2	239314
553	305809	169112377	23.5160	8.2081	2.74273	1.80832	1737.3	240182
554	306916	170031464	23.5372	8.2130	2.74351	1.80505	1740.4	241051
555	308025	170953875	23.5584	8.2180	2.74429	1.80180	1743.6	241922
556	309136	171879616	23.5797	8.2229	2.74507	1.79856	1746.7	242795
557	310249	172808693	23.6008	8.2278	2.74586	1.79533	1749.9	243669
558	311364	173741112	23.6220	8.2327	2.74663	1.79211	1753.0	244545
559	312481	174676879	23.6432	8.2377	2.74741	1.78891	1756.2	245422
560	313600	175616000	23.6643	8.2426	2.74819	1.78571	1759.3	246301
561	314721	176558481	23.6854	8.2475	2.74896	1.78253	1762.4	247181
562	315844	177504328	23.7065	8.2524	2.74974	1.77936	1765.6	248063
563	316969	178453547	23.7276	8.2573	2.75051	1.77620	1768.7	248947
564	318096	179406144	23.7487	8.2621	2.75128	1.77305	1771.9	249832
565	319225	180362125	23.7697	8.2670	2.75205	1.76991	1775.0	250719
566	320356	181321496	23.7908	8.2719	2.75282	1.76678	1778.1	251607
567	321489	182284263	23.8118	8.2768	2.75358	1.76367	1781.3	252497
568	322624	183250432	23.8328	8.2816	2.75435	1.76056	1784.4	253388
569	323761	184220009	23.8537	8.2865	2.75511	1.75747	1787.6	254281
570	324900	185193000	23.8747	8.2913	2.75587	1.75439	1790.7	255176
571	326041	186169411	23.8956	8.2962	2.75664	1.75131	1793.8	256072
572	327184	187149248	23.9165	8.3010	2.75740	1.74825	1797.0	256970
573	328329	188132517	23.9374	8.3059	2.75815	1.74520	1800.1	257869
574	329476	189119224	23.9583	8.3107	2.75891	1.74216	1803.3	258770
575	330625	190109375	23.9792	8.3155	2.75967	1.73913	1806.4	259672
576	331776	191102976	24.0000	8.3203	2.76042	1.73611	1809.6	260576
577	332929	192100033	24.0208	8.3251	2.76118	1.73310	1812.7	261482
578	334084	193100552	24.0416	8.3300	2.76193	1.73010	1815.8	262389
579	335241	194104539	24.0624	8.3348	2.76268	1.72712	1819.0	263298
580	336400	195112000	24.0832	8.3396	2.76343	1.72414	1822.1	264208
581	337561	196122941	24.1039	8.3443	2.76418	1.72117	1825.3	265120
582	338724	197137368	24.1247	8.3491	2.76492	1.71821	1828.4	266033
583	339889	198155287	24.1454	8.3539	2.76567	1.71527	1831.6	266948
584	341056	199176704	24.1661	8.3587	2.76641	1.71233	1834.7	267865
585	342225	200201625	24.1868	8.3634	2.76716	1.70940	1837.8	268783
586	343396	201230056	24.2074	8.3682	2.76790	1.70648	1841.0	269703
587	344569	202262003	24.2281	8.3730	2.76864	1.70358	1844.1	270624
588	345744	203297472	24.2487	8.3777	2.76938	1.70068	1847.3	271547
589	346921	204336469	24.2693	8.3825	2.77012	1.69779	1850.4	272471
590	348100	205379000	24.2899	8.3872	2.77085	1.69492	1853.5	273397
591	349281	206425071	24.3105	8.3919	2.77159	1.69205	1856.7	274325
592	350464	207474688	24.3311	8.3967	2.77232	1.68919	1859.8	275254
593	351649	208527857	24.3516	8.4014	2.77305	1.68634	1863.0	276184
594	352836	209584584	24.3721	8.4061	2.77379	1.68350	1866.1	277117
595	354025	210644875	24.3926	8.4108	2.77452	1.68067	1869.2	278051
596	355216	211708736	24.4131	8.4155	2.77525	1.67785	1872.4	278986
597	356409	212776173	24.4336	8.4202	2.77597	1.67504	1875.5	279923
598	357604	213847192	24.4540	8.4249	2.77670	1.67224	1878.7	280862
599	358801	214921799	24.4745	8.4296	2.77743	1.66945	1881.8	281802

FUNCTIONS OF NUMBERS

600
649

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
600	360000	216000000	24.4949	8.4343	2.77815	1.66667	1885.0	282743
601	361201	217081801	24.5153	8.4390	2.77887	1.66389	1888.1	283687
602	362404	218167208	24.5357	8.4437	2.77960	1.66113	1891.2	284631
603	363609	219256227	24.5561	8.4484	2.78032	1.65837	1894.4	285578
604	364816	220348864	24.5764	8.4530	2.78104	1.65563	1897.5	286526
605	366025	221445125	24.5967	8.4577	2.78176	1.65289	1900.7	287475
606	367236	222545016	24.6171	8.4623	2.78247	1.65017	1903.8	288426
607	368449	223648543	24.6374	8.4670	2.78319	1.64745	1906.9	289379
608	369664	224755712	24.6577	8.4716	2.78390	1.64474	1910.1	290333
609	370881	225866529	24.6779	8.4763	2.78462	1.64204	1913.2	291289
610	372100	226981000	24.6982	8.4809	2.78533	1.63934	1916.4	292247
611	373321	228099131	24.7184	8.4856	2.78604	1.63666	1919.5	293206
612	374544	229220928	24.7386	8.4902	2.78675	1.63399	1922.7	294166
613	375769	230346397	24.7588	8.4948	2.78746	1.63132	1925.8	295128
614	376996	231475544	24.7790	8.4994	2.78817	1.62866	1928.9	296092
615	378225	232608375	24.7992	8.5040	2.78888	1.62602	1932.1	297057
616	379456	233744896	24.8193	8.5086	2.78958	1.62338	1935.2	298024
617	380689	234885113	24.8395	8.5132	2.79029	1.62075	1938.4	298992
618	381924	236029032	24.8596	8.5178	2.79099	1.61812	1941.5	299962
619	383161	237176659	24.8797	8.5224	2.79169	1.61551	1944.6	300934
620	384400	238328000	24.8998	8.5270	2.79239	1.61290	1947.8	301907
621	385641	239483061	24.9199	8.5316	2.79309	1.61031	1950.9	302882
622	386884	240641848	24.9399	8.5362	2.79379	1.60772	1954.1	303858
623	388129	241804367	24.9600	8.5408	2.79449	1.60514	1957.2	304836
624	389376	242970624	24.9800	8.5453	2.79518	1.60256	1960.4	305815
625	390625	244140625	25.0000	8.5499	2.79588	1.60000	1963.5	306796
626	391876	245314376	25.0200	8.5544	2.79657	1.59744	1966.6	307779
627	393129	246491883	25.0400	8.5590	2.79727	1.59490	1969.8	308763
628	394384	247673152	25.0599	8.5635	2.79796	1.59236	1972.9	309748
629	395641	248858189	25.0799	8.5681	2.79865	1.58983	1976.1	310736
630	396900	250047000	25.0998	8.5726	2.79934	1.58730	1979.2	311725
631	398161	251239591	25.1197	8.5772	2.80003	1.58479	1982.3	312715
632	399424	252435968	25.1396	8.5817	2.80072	1.58228	1985.5	313707
633	400689	253636137	25.1595	8.5862	2.80140	1.57978	1988.6	314700
634	401956	254840104	25.1794	8.5907	2.80209	1.57729	1991.8	315696
635	403225	256047875	25.1992	8.5952	2.80277	1.57480	1994.9	316692
636	404496	257259456	25.2190	8.5997	2.80346	1.57233	1998.1	317690
637	405769	258474853	25.2389	8.6043	2.80414	1.56986	2001.2	318690
638	407044	259694072	25.2587	8.6088	2.80482	1.56740	2004.3	319692
639	408321	260917119	25.2784	8.6132	2.80550	1.56495	2007.5	320695
640	409600	262144000	25.2982	8.6177	2.80618	1.56250	2010.6	321699
641	410881	263374721	25.3180	8.6222	2.80686	1.56006	2013.8	322705
642	412164	264609288	25.3377	8.6267	2.80754	1.55763	2016.9	323713
643	413449	265847707	25.3574	8.6312	2.80821	1.55521	2020.0	324722
644	414736	267089984	25.3772	8.6357	2.80889	1.55280	2023.2	325733
645	416025	268336125	25.3969	8.6401	2.80956	1.55039	2026.3	326745
646	417316	269586136	25.4165	8.6446	2.81023	1.54799	2029.5	327759
647	418609	270840023	25.4362	8.6490	2.81090	1.54560	2032.6	328775
648	419904	272097792	25.4558	8.6535	2.81158	1.54321	2035.8	329792
649	421201	273359449	25.4755	8.6579	2.81224	1.54083	2038.9	330810

FUNCTIONS OF NUMBERS

650
699

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
650	422500	274625000	25.4951	8.6624	2.81291	1.53846	2042.0	331831
651	423801	275894451	25.5147	8.6668	2.81358	1.53610	2045.2	332853
652	425104	277167808	25.5343	8.6713	2.81425	1.53374	2048.3	333876
653	426409	278445077	25.5539	8.6757	2.81491	1.53139	2051.5	334901
654	427716	279726264	25.5734	8.6801	2.81558	1.52905	2054.6	335927
655	429025	281011375	25.5930	8.6845	2.81624	1.52672	2057.7	336955
656	430336	282300416	25.6125	8.6890	2.81690	1.52439	2060.9	337985
657	431649	283593393	25.6320	8.6934	2.81757	1.52207	2064.0	339016
658	432964	284890312	25.6515	8.6978	2.81823	1.51976	2067.2	340049
659	434281	286191179	25.6710	8.7022	2.81889	1.51745	2070.3	341084
660	435600	287496000	25.6905	8.7066	2.81954	1.51515	2073.5	342119
661	436921	288804781	25.7099	8.7110	2.82020	1.51286	2076.6	343157
662	438244	290117528	25.7294	8.7154	2.82086	1.51057	2079.7	344196
663	439569	291434247	25.7488	8.7198	2.82151	1.50830	2082.9	345237
664	440896	292754944	25.7682	8.7241	2.82217	1.50602	2086.0	346279
665	442225	294079625	25.7876	8.7285	2.82282	1.50376	2089.2	347323
666	443556	295408296	25.8070	8.7329	2.82347	1.50150	2092.3	348368
667	444889	296740963	25.8263	8.7373	2.82413	1.49925	2095.4	349415
668	446224	298077632	25.8457	8.7416	2.82478	1.49701	2098.6	350464
669	447561	299418309	25.8650	8.7460	2.82543	1.49477	2101.7	351514
670	448900	300763000	25.8844	8.7503	2.82607	1.49254	2104.9	352565
671	450241	302111711	25.9037	8.7547	2.82672	1.49031	2108.0	353618
672	451584	303464448	25.9230	8.7590	2.82737	1.48810	2111.2	354673
673	452929	304821217	25.9422	8.7634	2.82082	1.48588	2114.3	355730
674	454276	306182024	25.9615	8.7677	2.82866	1.48368	2117.4	356788
675	455625	307546875	25.9808	8.7721	2.82930	1.48148	2120.6	357847
676	456976	308915776	26.0000	8.7764	2.82995	1.47929	2123.7	358908
677	458329	310288733	26.0192	8.7807	2.83059	1.47710	2126.9	359971
678	459684	311665752	26.0384	8.7850	2.83123	1.47493	2130.0	361035
679	461041	313046839	26.0576	8.7893	2.83187	1.47275	2133.1	362101
680	462400	314432000	26.0768	8.7937	2.83251	1.47059	2136.3	363168
681	463761	315821241	26.0960	8.7980	2.83315	1.46843	2139.4	364237
682	465124	317214568	26.1151	8.8023	2.83378	1.46628	2142.6	365308
683	466489	318611987	26.1343	8.8066	2.83442	1.46413	2145.7	366380
684	467856	320013504	26.1534	8.8109	2.83506	1.46199	2148.8	367453
685	469225	321419125	26.1725	8.8152	2.83569	1.45985	2152.0	368528
686	470596	322828856	26.1916	8.8194	2.83632	1.45773	2155.1	369605
687	471969	324242703	26.2107	8.8237	2.83696	1.45560	2158.3	370684
688	473344	325660672	26.2298	8.8280	2.83759	1.45349	2161.4	371764
689	474721	327082769	26.2488	8.8323	2.83822	1.45138	2164.6	372845
690	476100	323509000	26.2679	8.8366	2.83885	1.44928	2167.7	373928
691	477481	329939371	26.2869	8.8408	2.83948	1.44718	2170.8	375013
692	478864	331373888	26.3059	8.8451	2.84011	1.44509	2174.0	376099
693	480249	332812557	26.3249	8.8493	2.84073	1.44300	2177.1	377187
694	481636	334255384	26.3439	8.8536	2.84136	1.44092	2180.3	378276
695	483025	335702375	26.3629	8.8578	2.84198	1.43885	2183.4	379367
696	484416	337153536	26.3818	8.8621	2.84261	1.43678	2186.5	380459
697	485809	338608873	26.4008	8.8663	2.84323	1.43472	2189.7	381553
698	487204	340068392	26.4197	8.8706	2.84386	1.43266	2192.8	382649
699	488601	341532099	26.4386	8.8748	2.84448	1.43062	2196.0	383746

700
749

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
700	490000	343000000	26.4575	8.8790	2.84510	1.42857	2199.1	384845
701	491401	344472101	26.4764	8.8833	2.84572	1.42653	2202.3	385945
702	492804	345948408	26.4953	8.8875	2.84634	1.42450	2205.4	387047
703	494209	347428927	26.5141	8.8917	2.84696	1.42248	2208.5	388151
704	495616	348913664	26.5330	8.8959	2.84757	1.42045	2211.7	389256
705	497025	350402625	26.5518	8.9001	2.84819	1.41844	2214.8	390363
706	498436	351895816	26.5707	8.9043	2.84880	1.41643	2218.0	391471
707	499849	353393243	26.5895	8.9085	2.84942	1.41443	2221.1	392580
708	501264	354894912	26.6083	8.9127	2.85003	1.41243	2224.2	393692
709	502681	356400829	26.6271	8.9169	2.85065	1.41044	2227.4	394805
710	504100	357911000	26.6458	8.9211	2.85126	1.40845	2230.5	395919
711	505521	359425431	26.6646	8.9253	2.85187	1.40647	2233.7	397035
712	506944	360944128	26.6833	8.9295	2.85248	1.40449	2236.8	398153
713	508369	362467097	26.7021	8.9337	2.85309	1.40252	2240.0	399272
714	509796	363994344	26.7208	8.9378	2.85370	1.40056	2243.1	400393
715	511225	365525875	26.7395	8.9420	2.85431	1.39860	2246.2	401515
716	512656	367061696	26.7582	8.9462	2.85491	1.39665	2249.4	402639
717	514089	368601813	26.7769	8.9503	2.85552	1.39470	2252.5	403765
718	515524	370146232	26.7955	8.9545	2.85612	1.39276	2255.7	404892
719	516961	371694959	26.8142	8.9587	2.85673	1.39082	2258.8	406020
720	518400	373248000	26.8328	8.9628	2.85733	1.38889	2261.9	407150
721	5198	374805361	26.8514	8.9670	2.85794	1.38696	2265.1	408282
722	521284	376367048	26.8701	8.9711	2.85854	1.38504	2268.2	409415
723	522729	377933067	26.8887	8.9752	2.85914	1.38313	2271.4	410550
724	524176	379503424	26.9072	8.9794	2.85974	1.38122	2274.5	411687
725	525625	381078125	26.9258	8.9835	2.86034	1.37931	2277.7	412825
726	527076	382657176	26.9444	8.9876	2.86094	1.37741	2280.8	413965
727	528529	384240583	26.9629	8.9918	2.86153	1.37552	2283.9	415106
728	529984	385828352	26.9815	8.9959	2.86213	1.37363	2287.1	416248
729	531441	387420489	27.0000	9.0000	2.86273	1.37174	2290.2	417393
730	532900	389017000	27.0185	9.0041	2.86332	1.36986	2293.4	418539
731	534361	390617891	27.0370	9.0082	2.86392	1.36799	2296.5	419686
732	535824	392223168	27.0555	9.0123	2.86451	1.36612	2299.6	420835
733	537289	393832837	27.0740	9.0164	2.86510	1.36426	2302.8	421986
734	538756	395446904	27.0924	9.0205	2.86570	1.36240	2305.9	423138
735	540225	397065375	27.1109	9.0246	2.86629	1.36054	2309.1	424293
736	541696	398688256	27.1293	9.0287	2.86688	1.35870	2312.2	425447
737	543169	400315553	27.1477	9.0328	2.86747	1.35685	2315.4	426604
738	544644	401947272	27.1662	9.0369	2.86806	1.35501	2318.5	427762
739	546121	403583419	27.1846	9.0410	2.86864	1.35318	2321.6	428922
740	547600	405224000	27.2029	9.0450	2.86923	1.35135	2324.8	430084
741	549081	406869021	27.2213	9.0491	2.86982	1.34953	2327.9	431247
742	550564	408518488	27.2397	9.0532	2.87040	1.34771	2331.1	432412
743	552049	410172407	27.2580	9.0572	2.87099	1.34590	2334.2	433578
744	553536	411830784	27.2764	9.0613	2.87157	1.34409	2337.3	434746
745	555025	413493625	27.2947	9.0654	2.87216	1.34228	2340.5	435916
746	556516	415160936	27.3130	9.0694	2.87274	1.34048	2343.6	437087
747	558009	416832723	27.3313	9.0735	2.87332	1.33869	2346.8	438259
748	559504	418508992	27.3496	9.0775	2.87390	1.33690	2349.9	439433
749	561001	420189749	27.3679	9.0816	2.87448	1.33511	2353.1	440609

750
799

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
750	562500	421875000	27.3861	9.0856	2.87506	1.33333	2356.2	441786
751	564001	423564751	27.4044	9.0896	2.87564	1.33156	2359.3	442965
752	565504	425259008	27.4226	9.0937	2.87622	1.32979	2362.5	444146
753	567009	426957777	27.4408	9.0977	2.87680	1.32802	2365.6	445328
754	568516	428661064	27.4591	9.1017	2.87737	1.32626	2368.8	446511
755	570025	430368875	27.4773	9.1057	2.87795	1.32450	2371.9	447697
756	571536	432081216	27.4955	9.1098	2.87852	1.32275	2375.0	448883
757	573049	433798093	27.5136	9.1138	2.87910	1.32100	2378.2	450072
758	574564	435519512	27.5318	9.1178	2.87967	1.31926	2381.3	451262
759	576081	437245479	27.5500	9.1218	2.88024	1.31752	2384.5	452453
760	577600	438976000	27.5681	9.1258	2.88081	1.31579	2387.6	453646
761	579121	440711081	27.5862	9.1298	2.88138	1.31406	2390.8	454841
762	580644	442450728	27.6043	9.1338	2.88196	1.31234	2393.9	456037
763	582169	444194947	27.6225	9.1378	2.88252	1.31062	2397.0	457234
764	583696	445943744	27.6405	9.1418	2.88309	1.30890	2400.2	458434
765	585225	447697125	27.6586	9.1458	2.88366	1.30719	2403.3	459635
766	586756	449455096	27.6767	9.1498	2.88423	1.30548	2406.5	460837
767	588289	451217663	27.6948	9.1537	2.88480	1.30378	2409.6	462041
768	589824	452984832	27.7128	9.1577	2.88536	1.30208	2412.7	463247
769	591361	454756609	27.7308	9.1617	2.88593	1.30039	2415.9	464454
770	592900	456533000	27.7489	9.1657	2.88640	1.29870	2419.0	465663
771	594441	458314011	27.7669	9.1696	2.88705	1.29702	2422.2	466873
772	595984	460099648	27.7849	9.1736	2.88762	1.29534	2425.3	468085
773	597529	461889917	27.8029	9.1775	2.88818	1.29366	2428.5	469298
774	599076	463684824	27.8209	9.1815	2.88874	1.29199	2431.6	470513
775	600625	465484375	27.8388	9.1855	2.88930	1.29032	2434.7	471730
776	602176	467288576	27.8568	9.1894	2.88986	1.28866	2437.9	472948
777	603729	469097433	27.8747	9.1933	2.89042	1.28700	2441.0	474168
778	605284	470910952	27.8927	9.1973	2.89098	1.28535	2444.2	475389
779	606841	472729139	27.9106	9.2012	2.89154	1.28370	2447.3	476612
780	608400	474552000	27.9285	9.2052	2.89209	1.28205	2450.4	477836
781	609961	476379541	27.9464	9.2091	2.89265	1.28041	2453.6	479062
782	611524	478211768	27.9643	9.2130	2.89321	1.27877	2456.7	480290
783	613089	480048687	27.9821	9.2170	2.89376	1.27714	2459.9	481519
784	614656	481890304	28.0000	9.2209	2.89432	1.27551	2463.0	482750
785	616225	483736625	28.0179	9.2248	2.89487	1.27389	2466.2	483982
786	617796	485587656	28.0357	9.2287	2.89542	1.27226	2469.3	485216
787	619369	487443403	28.0535	9.2326	2.89597	1.27065	2472.4	486451
788	620944	489303872	28.0713	9.2365	2.89653	1.26904	2475.6	487688
789	622521	491169069	28.0891	9.2404	2.89708	1.26743	2478.7	488927
790	624100	493039000	28.1069	9.2443	2.89763	1.26582	2481.9	490167
791	625681	494913671	28.1247	9.2482	2.89818	1.26422	2485.0	491409
792	627264	496793088	28.1425	9.2521	2.89873	1.26263	2488.1	492652
793	628849	498677257	28.1603	9.2560	2.89927	1.26103	2491.3	493897
794	630436	500566184	28.1780	9.2599	2.89982	1.25945	2494.4	495143
795	632025	502459875	28.1957	9.2638	2.90037	1.25786	2497.6	496391
796	633616	504358336	28.2135	9.2677	2.90091	1.25628	2500.7	497641
797	635209	506261573	28.2312	9.2716	2.90146	1.25471	2503.8	498892
798	636804	508169592	28.2489	9.2754	2.90200	1.25313	2507.0	500145
799	638401	510082399	28.2666	9.2793	2.90255	1.25156	2510.1	501399

800
849

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
800	640000	512000000	28.2843	9.2832	2.90309	1.25000	2513.3	502655
801	641601	513922401	28.3019	9.2870	2.90363	1.24844	2516.4	503912
802	643204	515849608	28.3196	9.2909	2.90417	1.24688	2519.6	505171
803	644809	517781627	28.3373	9.2948	2.90472	1.24533	2522.7	506432
804	646416	519718464	28.3549	9.2986	2.90526	1.24378	2525.8	507694
805	648025	521660125	28.3725	9.3025	2.90580	1.24224	2529.0	508958
806	649636	523606616	28.3901	9.3063	2.90634	1.24069	2532.1	510223
807	651249	525557943	28.4077	9.3102	2.90687	1.23916	2535.3	411490
808	652864	527514112	28.4253	9.3140	2.90741	1.23762	2538.4	512758
809	654481	529475129	28.4429	9.3179	2.90795	1.23609	2541.5	514028
810	656100	531441000	28.4605	9.3217	2.90849	1.23457	2544.7	515300
811	657721	533411731	28.4781	9.3255	2.90902	1.23305	2547.8	516573
812	659344	535387328	28.4956	9.3294	2.90956	1.23153	2551.0	517848
813	660969	537367797	28.5132	9.3332	2.91009	1.23001	2554.1	519124
814	662596	539353144	28.5307	9.3370	2.91062	1.22850	2557.3	520402
815	664225	541343375	28.5482	9.3408	2.91116	1.22699	2560.4	521681
816	665856	543338496	28.5657	9.3447	2.91169	1.22549	2563.5	522962
817	667489	545338513	28.5832	9.3485	2.91222	1.22399	2566.7	524245
818	669124	547343432	28.6007	9.3523	2.91275	1.22249	2569.8	525529
819	670761	549353259	28.6182	9.3561	2.91328	1.22100	2573.0	526814
820	672400	551368000	28.6356	9.3599	2.91381	1.21951	2576.1	528102
821	674041	553387661	28.6531	9.3637	2.91434	1.21803	2579.2	529391
822	675684	555412248	28.6705	9.3675	2.91487	1.21655	2582.4	530681
823	677329	557441767	28.6880	9.3713	2.91540	1.21507	2585.5	531973
824	678976	559476224	28.7054	9.3751	2.91593	1.21359	2588.7	533267
825	680625	561515625	28.7228	9.3789	2.91645	1.21212	2591.8	534562
826	682276	563559976	28.7402	9.3827	2.91698	1.21065	2595.0	535858
827	683929	565609283	28.7576	9.3865	2.91751	1.20919	2598.1	537157
828	685584	567663552	28.7750	9.3902	2.91803	1.20773	2601.2	538456
829	687241	569722789	28.7924	9.3940	2.91855	1.20627	2604.4	539758
830	688900	571787000	28.8097	9.3978	2.91908	1.20482	2607.5	541061
831	690561	573856191	28.8271	9.4016	2.91960	1.20337	2610.7	542365
832	692224	575930368	28.8444	9.4053	2.92012	1.20192	2613.8	543671
833	693889	578009537	28.8617	9.4091	2.92065	1.20048	2616.9	544979
834	695556	580093704	28.8791	9.4129	2.92117	1.19904	2620.1	546288
835	697225	582182875	28.8964	9.4166	2.92169	1.19760	2623.2	547599
836	698896	584277056	28.9137	9.4204	2.92221	1.19617	2626.4	548912
837	700569	586376253	28.9310	9.4241	2.92273	1.19474	2629.5	550226
838	702244	588480472	28.9482	9.4279	2.92324	1.19332	2632.7	551541
839	703921	590589719	28.9655	9.4316	2.92376	1.19190	2635.8	552858
840	705600	592704000	28.9828	9.4354	2.92428	1.19048	2638.9	554177
841	707281	594823321	29.0000	9.4391	2.92480	1.18906	2642.1	555497
842	708964	596947688	29.0172	9.4429	2.92531	1.18765	2645.2	556819
843	710649	599077107	29.0345	9.4466	2.92583	1.18624	2648.4	558142
844	712336	601211584	29.0517	9.4503	2.92634	1.18483	2651.5	559467
845	714025	603351125	29.0689	9.4541	2.92686	1.18343	2654.6	560794
846	715716	605495736	29.0861	9.4578	2.92737	1.18203	2657.8	562122
847	717409	607645423	29.1033	9.4615	2.92788	1.18064	2660.9	563452
848	719104	609800192	29.1204	9.4652	2.92840	1.17925	2664.1	564783
849	720801	611960049	29.1376	9.4690	2.92891	1.17786	2667.2	566116

850
899

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
850	722500	614125000	29.1548	9.4727	2.92942	1.17647	2670.4	567450
851	724201	616295051	29.1719	9.4764	2.92993	1.17509	2673.5	568786
852	725904	618470208	29.1890	9.4801	2.93044	1.17371	2676.6	570124
853	727609	620650477	29.2062	9.4838	2.93095	1.17233	2679.8	571463
854	729316	622835864	29.2233	9.4875	2.93146	1.17096	2682.9	572803
855	731025	625026375	29.2404	9.4912	2.93197	1.16959	2686.1	574146
856	732736	627222016	29.2575	9.4949	2.93247	1.16822	2689.2	575490
857	734449	629422793	29.2746	9.4986	2.93298	1.16686	2692.3	576835
858	736164	631628712	29.2916	9.5023	2.93349	1.16550	2695.5	578182
859	737881	633839779	29.3087	9.5060	2.93399	1.16414	2698.6	579530
860	739600	636056000	29.3258	9.5097	2.93450	1.16279	2701.8	580880
861	741321	638277381	29.3428	9.5134	2.93500	1.16144	2704.9	582232
862	743044	640503928	29.3598	9.5171	2.93551	1.16009	2708.1	583585
863	744769	642735647	29.3769	9.5207	2.93601	1.15875	2711.2	584940
864	746496	644972544	29.3939	9.5244	2.93651	1.15741	2714.3	586297
865	748225	647214625	29.4109	9.5281	2.93702	1.15607	2717.5	587655
866	749956	649461896	29.4279	9.5317	2.93752	1.15473	2720.6	589014
867	751689	651714363	29.4449	9.5354	2.93802	1.15340	2723.8	590375
868	753424	653972032	29.4618	9.5391	2.93852	1.15207	2726.9	591738
869	755161	656234909	29.4788	9.5427	2.93902	1.15075	2730.0	593102
870	756900	658503000	29.4958	9.5464	2.93952	1.14943	2733.2	594468
871	758641	660776311	29.5127	9.5501	2.94002	1.14811	2736.3	595835
872	760384	663054848	29.5296	9.5537	2.94052	1.14679	2739.5	597204
873	762129	665338617	29.5466	9.5574	2.94101	1.14548	2742.6	598575
874	763876	667627624	29.5635	9,5610	2.94151	1.14416	2745.8	599947
875	765625	669921875	29.5804	9.5647	2.94201	1.14286	2748.9	601320
876	767376	672221376	29.5973	9.5683	2.94250	1.14155	2752.0	602696
877	769129	674526133	29.6142	9.5719	2.94300	1.14025	2755.2	604073
878	770884	676836152	29.6311	9.5756	2.94349	1.13895	2758.3	605451
879	772641	679151439	29.6479	9.5792	2.94399	1.13766	2761.5	606831
880	774400	681472000	29.6648	9.5828	2.94448	1.13636	2764.6	608212
881	776161	683797841	29.6816	9.5865	2.94498	1.13507	2767.7	609595
882	777924	686128968	29.6985	9.5901	2.94547	1.13379	2770.9	610980
883	779689	688465387	29.7153	9.5937	2.94596	1.13250	2774.0	612366
884	781456	690807104	29.7321	9.5973	2.94645	1.13122	2777.2	613754
885	783225	693154125	29.7489	9.6010	2.94694	1.12994	2780.3	615143
886	784996	695506456	29.7658	9.6046	2.94743	1.12867	2783.5	616534
887	786769	697864103	29.7825	9.6082	2.94792	1.12740	2786.6	617927
888	788544	700227072	29.7993	9.6118	2.94841	1.12613	2789.7	619321
889	790321	702595369	29.8161	9.6154	2.94890	1.12486	2792.9	620717
890	792100	704969000	29.8329	9.6190	2.94939	1.12360	2796.0	622114
891	793881	707347971	29.8496	9.6226	2.94988	1.12233	2799.2	623513
892	795664	709732288	29.8664	9.6262	2.95036	1.12108	2802.3	624913
893	797449	712121957	29.8831	9.6298	2.95085	1.11982	2805.4	626315
894	799236	714516984	29.8998	9.6334	2.95134	1.11857	2808.6	627718
895	801025	716917375	29.9166	9.6370	2.95182	1.11732	2811.7	629124
896	802816	719323136	29.9333	9.6406	2.95231	1.11607	2814.9	630530
897	804609	721734273	29.9500	9.6442	2.95279	1.11483	2818.0	631938
898	806404	724150792	29.9666	9.6477	2.95328	1.11359	2821.2	633348
899	808201	726572699	29.9833	9.6513	2.95376	1.11235	2824.3	634760

900
949

FUNCTIONS OF NUMBERS

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
900	810000	729000000	30.0000	9.6549	2.95424	1.11111	2827.4	636173
901	811801	731432701	30.0167	9.6585	2.95472	1.10988	2830.6	637587
902	813604	733870808	30.0333	9.6620	2.95521	1.10865	2833.7	639003
903	815409	736314327	30.0500	9.6656	2.95569	1.10742	2836.9	640421
904	817216	738763264	30.0666	9.6692	2.95617	1.10619	2840.0	641840
905	819025	741217625	30.0832	9.6727	2.95665	1.10497	2843.1	643261
906	820836	743677416	30.0998	9.6763	2.95713	1.10375	2846.3	644683
907	822649	746142643	30.1164	9.6799	2.95761	1.10254	2849.4	646107
908	824464	748613312	30.1330	9.6834	2.95809	1.10132	2852.6	647533
909	826281	751089429	30.1496	9.6870	2.95856	1.10011	2855.7	648960
910	828100	753571000	30.1662	9.6905	2.95904	1.09890	2858.8	650388
911	829921	756058031	30.1828	9.6941	2.95952	1.09769	2862.0	651818
912	831744	758550528	30.1993	9.6976	2.95999	1.09649	2865.1	653250
913	833569	761048497	30.2159	9.7012	2.96047	1.09529	2868.3	654684
914	835396	763551944	30.2324	9.7047	2.96095	1.09409	2871.4	656118
915	837225	766060875	30.2490	9.7082	2.96142	1.09290	2874.6	657555
916	839056	768575296	30.2655	9.7118	2.96190	1.09170	2877.7	658993
917	840889	771095213	30.2820	9.7153	2.96237	1.09051	2880.8	660433
918	842724	773620632	30.2985	9.7188	2.96284	1.08932	2884.0	661874
919	844561	776151559	30.3150	9.7224	2.96332	1.08814	2887.1	663317
920	846400	778688000	30.3315	9.7259	2.96379	1.08696	2890.3	664761
921	848241	781229961	30.3480	9.7294	2.96426	1.08578	2893.4	666207
922	850084	783777448	30.3645	9.7329	2.96473	1.08460	2896.5	667654
923	851929	786330467	30.3809	9.7364	2.96520	1.08342	2899.7	669103
924	853776	788889024	30.3974	9.7400	2.96567	1.08225	2902.8	670554
925	855625	791453125	30.4138	9.7435	2.96614	1.08108	2906.0	672006
926	857476	794022776	30.4302	9.7470	2.96661	1.07991	2909.1	673460
927	859329	796597983	30.4467	9.7505	2.96708	1.07875	2912.3	674915
928	861184	799178752	30.4631	9.7540	2.96755	1.07759	2915.4	676372
929	863041	801765089	30.4795	9.7575	2.96802	1.07643	2918.5	677831
930	864900	804357000	30.4959	9.7610	2.96848	1.07527	2921.7	679291
931	866761	806954491	30.5123	9.7645	2.96895	1.07411	2924.8	680752
932	868624	809557568	30.5287	9.7680	2.96942	1.07296	2928.0	682216
933	870489	812166237	30.5450	9.7715	2.96988	1.07181	2931.1	683680
934	872356	814780504	30.5614	9.7750	2.97035	1.07066	2934.2	685147
935	874225	817400375	30.5778	9.7785	2.97081	1.06952	2937.4	686615
936	876096	820025856	30.5941	9.7819	2.97128	1.06838	2940.5	688084
937	877969	822656953	30.6105	9.7854	2.97174	1.06724	2943.7	689555
938	879844	825293672	30.6268	9.7889	2.97220	1.06610	2946.8	691028
939	881721	827936019	30.6431	9.7924	2.97267	1.06496	2950.0	692502
940	883600	830584000	30.6594	9.7959	2.97313	1.06383	2953.1	693978
941	885481	833237621	30.6757	9.7993	2.97359	1.06270	2956.2	695455
942	887364	835896888	30.6920	9.8028	2.97405	1.06157	2959.4	696934
943	889249	838561807	30.7083	9.8063	2.97451	1.06045	2962.5	698415
944	891136	841232384	30.7246	9.8097	2.97497	1.05932	2965.7	699897
945	893025	843908625	30.7409	9.8132	2.97543	1.05820	2968.8	701380
946	894916	846590536	30.7571	9.8167	2.97589	1.05708	2971.9	702865
947	896809	849278123	30.7734	9.8201	2.97635	1.05597	2975.1	704352
948	898704	851971392	30.7896	9.8236	2.97681	1.05485	2978.2	705840
949	900601	854670349	30.8058	9.8270	2.97727	1.05374	2981.4	707330

950
999

FUNCTIONS OF NUMBERS

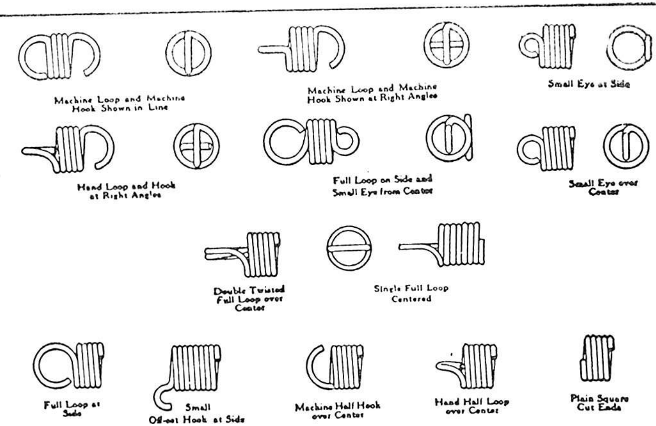
No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
950	902500	857375000	30.8221	9.8305	2.97772	1.05263	2984.5	708822
951	904401	860085351	30.8383	9.8339	2.97818	1.05152	2987.7	710315
952	906304	862801408	30.8545	9.8374	2.97864	1.05042	2990.8	711809
953	908209	865523177	30.8707	9.8408	2.97909	1.04932	2993.9	713306
954	910116	868250664	30.8869	9.8443	2.97955	1.04822	2997.1	714803
955	912025	870983875	30.9031	9.8477	2.98000	1.04712	3000.2	716303
956	913936	873722816	30.9192	9.8511	2.98046	1.04603	3003.4	717804
957	915849	876467493	30.9354	9.8546	2.98091	1.04493	3006.5	719306
958	917764	879217912	30.9516	9.8580	2.98137	1.04384	3009.6	720810
959	919681	881974079	30.9677	9.8614	2.98182	1.04275	3012.8	722316
960	921600	884736000	30.9839	9.8648	2.98227	1.04167	3015.9	723823
961	923521	887503681	31.0000	9.8683	2.98272	1.04058	3019.1	725332
962	925444	890277128	31.0161	9.8717	2.98318	1.03950	3022.2	726842
963	927369	893056347	31.0322	9.8751	2.98363	1.03842	3028.5	728354
964	929296	895841344	31.0483	9.8785	2.98408	1.03734	3028.5	729867
965	931225	898632125	31.0644	9.8819	2.98453	1.03627	3031.6	731382
966	933156	901428696	31.0805	9.8854	2.98498	1.03520	3034.8	732899
967	935089	904231063	31.0966	9.8888	2.98543	1.03413	3037.9	734417
968	937024	907039232	31.1127	9.8922	2.98588	1.03306	3041.1	735937
969	938961	909853209	31.1288	9.8956	2.98632	1.03199	3044.2	737458
970	940900	912673000	31.1448	9.8990	2.98677	1.03093	3047.3	738981
971	942841	915498611	31.1609	9.9024	2.98722	1.02987	3050.5	740506
972	944784	918330048	31.1769	9.9058	2.98767	1.02881	3053.6	742032
973	946729	921167317	31.1929	9.9092	2.98811	1.02775	3056.8	743559
974	948676	924010424	31.2090	9.9126	2.98856	1.02669	3059.9	745088
975	950625	926859375	31.2250	9.9160	2.98900	1.02564	3063.1	746619
976	952576	929714176	31.2410	9.9194	2.98945	1.02459	3066.2	748151
977	954529	932574833	31.2570	9.9227	2.98989	1.02354	3069.3	749685
978	956484	935441352	31.2730	9.9261	2.99034	1.02249	3072.5	751221
979	958441	938313739	31.2890	9.9295	2.99078	1.02145	3075.6	752758
980	960400	941192000	31.3050	9.9329	2.99123	1.02041	3078.8	754296
981	962361	944076141	31.3209	9.9363	2.99167	1.01937	3081.9	755837
982	964324	946966168	31.3369	9.9396	2.99211	1.01833	3085.0	757378
983	966289	949862087	31.3528	9.9430	2.99255	1.01729	3088.2	758922
984	968256	952763904	31.3688	9.9464	2.99300	1.01626	3091.3	760466
985	970225	955671625	31.3847	9.9497	2.99344	1.01523	3094.5	762013
986	972196	958585256	31.4006	9.9531	2.99388	1.01420	3097.6	763561
987	974169	961504803	31.4166	9.9565	2.99432	1.01317	3100.8	765111
988	976144	964430272	31.4325	9.9598	2.99476	1.01215	3103.9	766662
989	978121	967361669	31.4484	9.9632	2.99520	1.01112	3107.0	768214
990	980100	970299000	31.4643	9.9666	2.99564	1.01010	3110.2	769769
991	982081	973242271	31.4802	9.9699	2.99607	1.00908	3113.3	771325
992	984064	976191488	31.4960	9.9733	2.99651	1.00806	3116.5	772882
993	986049	979146657	31.5119	9.9766	2.99695	1.00705	3119.6	774441
994	988036	982107784	31.5278	9.9800	2.99739	1.00604	3122.7	776002
995	990025	985074875	31.5436	9.9833	2.99782	1.00503	3125.9	777564
996	992016	988047936	31.5595	9.9866	2.99826	1.00402	3129.0	779128
997	994009	991026973	31.5753	9.9900	2.99870	1.00301	3132.2	780693
998	996004	994011992	31.5911	9.9933	2.99913	1.00200	3135.3	782260
999	998001	997002999	31.6070	9.9967	2.99957	1.00100	3138.5	783828

TYPES OF ENDS

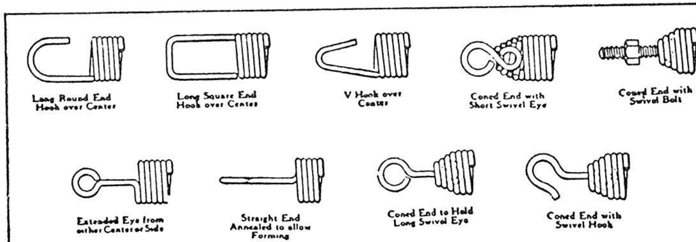
used on

EXTENSION SPRINGS

These drawings show only a few of the various types of ends used on Extension Springs

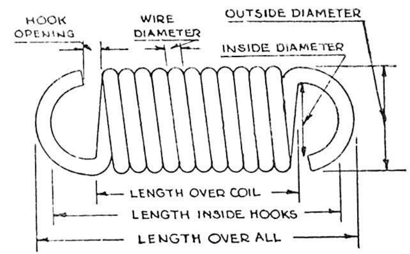


ALL THE ABOVE ENDS ARE STANDARD TYPES FOR WHICH NO SPECIAL TOOLS ARE REQUIRED!



THIS GROUP OF SPECIAL ENDS REQUIRE SPECIAL TOOLS

EXTENSION SPRINGS



(1) Free length ________ Maximum ________ Minimum ________
(over all) (over coil) (inside hooks)

(2) Controlling diameter: (a) Outside diameter Max. ________
(b) Inside diameter Min. ________
(c) Works inside ________
(d) Works over ________

(3) Wire size (if known) ________

(4) Material (kind and grade) ________

(5) Number of coils ________

(6) Style ends (for illustrations see back page)

(7) *Winding (left or right hand optional) ________
(see above for directional drawing of right hand winding)

(8) Finish (as specified)

(9) Load required at ________ Length inside hooks ________
(if wire size not specified) Length of coil ________

(10) Maximum length ________

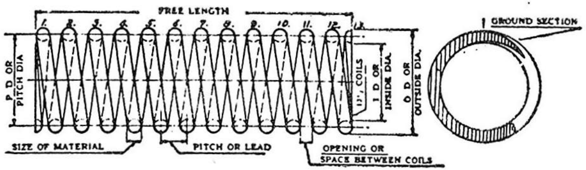
(11) Deflection or distance of travel ________

(12) Frequency of extension ________

(13) Is relative position of ends important? ________
(making the ends of springs bear a definite relation to each other usually adds to the cost of manufacture).

*NOTE: Extension springs made from tempered or hard-drawn wires can be and usually are wound with initial tension. Such tension may average 20% of the total safe stress of the springs, but will not increase the elastic limit.

COMPRESSION SPRINGS



(1) Free length ________ Maximum ________ Minimum ________

(2) Controlling diameter: (a) Outside diameter Max. ________
(b) Inside diameter Min. ________
(c) Pitch diameter ________
(d) Works inside hole ________
(e) Works over ________

(3) Wire size (if known) ________

(4) Material (kind and grade) ________

(5) Load ________ at deflected position of ________

(6) Style ends (see below) ________

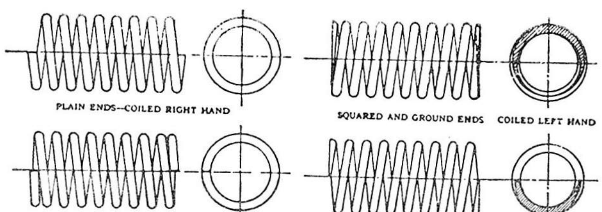
(7) *Winding (left or right hand optional) ________
(see above for directional drawing of right hand winding)

(8) Finish (as specified)

(9) Maximum solid length ________

(10) Frequency of compression ________

Additional information:



PLAIN ENDS—COILED RIGHT HAND

SQUARED AND GROUND ENDS — COILED LEFT HAND

SQUARED OR CLOSED ENDS NOT GROUND—COILED RIGHT HAND

PLAIN ENDS—GROUND COILED LEFT HAND

MANUFACTURING VARIATIONS

for coil springs made of wire up to and including 1-inch

* INDEX D/d. Coil Diameter, In.	Plus or Minus Variations in Diameter in Inches ** 4	8	12
1/8	0.0020	0.0030	0.0045
1/8 to 3/16	0.0030	0.0045	0.0060
3/16 to 1/4	0.0045	0.0060	0.0080
1/4 to 3/8	0.0060	0.0080	0.0100
3/8 to 1/2	0.0080	0.0100	0.0125
1/2 to 3/4	0.0100	0.0125	0.0150
3/4 to 1	0.0125	0.0150	0.0225
1 to 1 1/2	0.0150	0.0225	0.0313
1 1/2 to 2	0.0225	0.0313	0.0470
2 to 3	0.0470	0.0625	0.0938
3 to 4	0.0625	0.0938	0.1250
4 to 5	0.0937	0.1250	0.1560

Diameter range, in.	Tolerance, in.
up to 0.016	+0.00025
0.017-0.062	+0.0005
0.063-0.080	+0.0010
0.082-0.104	±0.0010
0.105-0.144	±0.0015
0.145 and up	±0.0020

INDEX D/d	Length Variations in Plus or Minus Per Inch of Spring Unfinished, Not Ground 4	8	12
5 coils per in.	0.020″	0.030″	0.040″
10 coils per in.	0.030″	0.040″	0.050″
15 coils per in.	0.040″	0.050″	0.060″
20 coils per in.	0.050″	0.060″	0.070″

INDEX D/d	Squareness Variations in Degrees for Ground End Springs 4	8	12
5 coils per in.	1 1/2 to 3 deg.	2 to 4 deg.	2 1/2 to 5 deg.
10 coils per in.	2 to 4 deg.	2 1/2 to 5 deg.	3 to 6 deg.
15 coils per in.	2 1/2 to 5 deg.	3 to 6 deg.	3 1/2 to 7 deg.
20 coils per in.	3 to 6 deg.	3 1/2 to 7 deg.	4 to 8 deg.

Coil Variations in Plus or Minus

4 coils to less—1/4 coil	8 to 15 coils—3/4 coil
4 or 8 coils—1/2 coil	15 to 25 coils—1 coil

*D/d:—"D" signifies outside diameter of coil. "d" signifies diameter of wire.

**4-8-12 signifies the ratio that is to be used to the nearest approximation. Example:—D/d 4 means a coil diameter of 4 times the wire diameter, and may be used in cases ranging from 3 to 6 times the wire diameter. 8 would then cover diameters of 7 to 10 times the wire diameter, and 12 covers coil diameters from 10 to 12 times wire diameters.

ALLOWABLE TOLERANCES IN COMPRESSION SPRING SPECIFICATIONS

Diameter of Coil

Outside Diameter O D.	Variation
Less than 1/8″	.003″
1/8 - 1/4	.005
1/4 - 1/2	.008
1/2 - 1	1/64
1 - 2	1/32
2 - 3	1/16
3 and Larger	3/32

Number of Coils

Number of Coils N	Variation
Less than 4	1/4
4 - 8	1/2
8 - 15	3/4
15 - 25	1
25 and More	1 1/2

Size of Wire

Wire Size	Variation
Finer than .020	.00025
.020 .040	.00050
.040 .060	.00075
.060 .080	.0010
.080 .177	.0015
.177 .375	.002
.375 and Coarser	.003

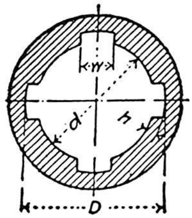
Springs to closer size and dimension limits can be manufactured but may require an increase in cost due to greater accuracy required in the manufacture of both the wire and the finished springs.

Variations above are Plus and Minus. They may be applied to commercial springs in which the outside diameter of the coil does not exceed 12 times the wire size.

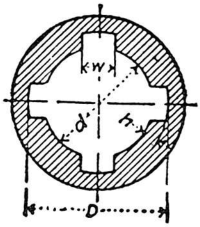
SPLINE FITTINGS

FOUR-SPLINE FITTINGS

(S. A. E. Standard)



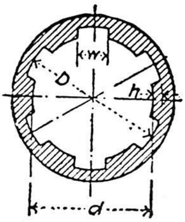
4A
W=0.241D
h=0.075D
d=0.850D



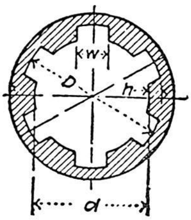
4B
W=0.241D
h=0.125D
d=0.750D

SIX-SPLINE FITTINGS

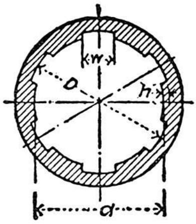
(S. A. E. Standard)



6A
W=0.250D
h=0.050D
d=0.900D



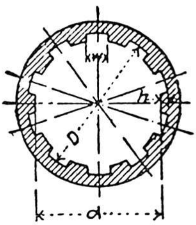
6B
W=0.250D
h=0.075D
d=0.850D



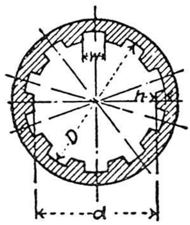
6C
W=0.250D
h=0.100D
d=0.800D

TEN-SPLINE FITTINGS

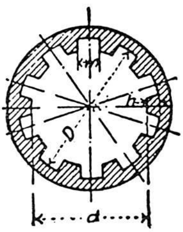
(S. A. E. Standard)



10A
W=0.156D
h=0.045D
d=0.910D



10B
W=0.156D
h=0.070D
d=0.860D



10C
W=0.156D
h=0.095D
d=0.810D

COMPOUND FOR WELDING CAST STEEL. Mix 41 parts of boracic acid, 35 parts of pure, dried common salt, 20 parts of ferrocyanide of potassium, 8 parts rosin and 4 parts carbonate of sodium. When this compound is to be used, a sufficient quantity is scattered upon the article to be welded, which has been heated to a light red heat. It is then heated to a strong yellow heat and the welding accomplished in the usual manner.

Limits for Turning and Grinding—The limits given in the table below are recommended for use in the manufacture of machine parts, to produce satisfactory commercial work. These limits should only be followed under ordinary conditions. For special cases, it may be necessary to increase or decrease the limits given in the table. The allowance to be used when rough turning parts to be ground varies from 0.010 to 0.030 inch; that is, a part to be ground to a diameter of 1 inch would be rough turned in the lathe to a diameter of from 1.010 to 1.015 inch, while a 3-inch shaft may have an allowance of from 0.015 to 0.025 inch. The allowance depends largely on the class of work.

Allowances for Fits

Grinding Limits for Cylindrical Parts

(+ Designates larger than nominal size; — Smaller than nominal size.)

Diameter, Inches	Limits, Inches	Diameter, Inches	Limits, Inches
Running Fits—Ordinary Speed		**Driving Fits—Ordinary**	
Up to ½	— 0.00025 to — 0.00075	Up to ½	+ 0.00075 to + 0.0015
½ to 1	— 0.00075 to — 0.0015	½ to 1	+ 0.001 to + 0.002
1 to 2	— 0.0015 to — 0.0025	1 to 2	+ 0.002 to + 0.003
2 to 3½	— 0.0025 to — 0.0035	2 to 3½	+ 0.003 to + 0.004
3½ to 6	— 0.0035 to — 0.005	3½ to 6	+ 0.004 to + 0.005
Running Fits—High-Speed, Heavy Pressure and Rocker Shafts		**Forced Fits**	
Up to ½	— 0.0005 to — 0.001	Up to ½	+ 0.00025 to + 0.0005
½ to 1	— 0.001 to — 0.002	½ to 1	+ 0.0015 to + 0.0025
1 to 2	— 0.002 to — 0.003	1 to 2	+ 0.0025 to + 0.004
2 to 3½	— 0.003 to — 0.0045	2 to 3½	+ 0.004 to + 0.006
3½ to 6	— 0.0045 to — 0.0065	3½ to 6	+ 0.006 to + 0.009
Sliding Fits		**Driving Fits—For such Pieces as are Required to be Readily Taken Apart**	
Up to ½	— 0.00025 to — 0.0005	Up to ½	0 to + 0.00025
½ to 1	— 0.0005 to — 0.001	½ to 1	+ 0.00025 to + 0.0005
1 to 2	— 0.001 to — 0.002	1 to 2	+ 0.0005 to + 0.00075
2 to 3½	— 0.002 to — 0.0035	2 to 3½	+ 0.00075 to + 0.001
3½ to 6	— 0.003 to — 0.005	3½ to 6	+ 0.001 to + 0.0015

How to Anneal Tool Steel

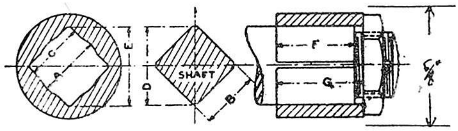
Carbon tool steel may be annealed by heating slowly and evenly to a cherry red and then placing in a box of lime or ashes to cool slowly. The steel should be completely covered and when it is cooled to room temperature will be ready for machining.

How to Anneal Brass

Brass that has been hardened through cold working may be annealed by heating to a dull red when held in dark shadow and plunging into cold water. Care must be taken not to overheat the brass.

To Remove Dry Paint from Iron or Steel — Dip a swab with a handle in a strong solution of oxalic acid. It softens at once upon being moistened

PROPORTIONS OF SQUARE SHAFTS AND FIT ALLOWANCES



Nominal Diam.	Permanent Fit $\frac{B}{D} = 0.80$							Sliding Fit $\frac{B}{D} = 0.73$				
	A	B	C	D	E	F	G	A	B	C	D	E
¼	0.193	0.189	0.187	0.250	0.260	5/16	3/8	0.257	0.248	0.250	0.344	0.354
		0.188	0.186	0.245	0.252				0.247	0.249	0.339	0.346
⅜	0.290	0.283	0.281	0.375	0.385	7/16	½	0.386	0.373	0.375	0.516	0.526
		0.282	0.280	0.370	0.377				0.372	0.374	0.511	0.518
½	0.386	0.377	0.375	0.500	0.510	11/16	¾	33/64	0.498	0.500	0.687	0.697
		0.376	0.374	0.495	0.502				0.497	0.499	0.682	0.689
⅝	33/64	0.502	0.500	0.625	0.635	11/16	¾	41/64	0.623	0.625	0.844	0.854
		0.501	0.499	0.620	0.627				0.622	0.624	0.839	0.846
¾	37/64	0.564	0.562	0.750	0.760	15/16	1	49/64	0.748	0.750	1.031	1.051
		0.563	0.561	0.745	0.752				0.747	0.749	1.026	1.036
⅞	45/64	0.689	0.687	0.875	0.885	1⅛	1¼	29/32	0.873	0.875	1.187	1.207
		0.688	0.686	0.870	0.877				0.872	0.874	1.182	1.192
1	27/32	0.815	0.812	1.000	1.020	1⅜	1½	1 1/32	0.998	1.000	1.375	1.395
		0.814	0.811	0.995	1.005				0.997	0.999	1.370	1.380
1⅛	29/32	0.878	0.875	1.125	1.145	1⅜	1¼	1 5/32	1.123	1.125	1.562	1.582
		0.877	0.874	1.120	1.130				1.122	1.124	1.557	1.567
1¼	1 1/32	1.103	1.000	1.250	1.270	1⅜	1½	1 9/32	1.248	1.250	1.687	1.707
		1.102	0.999	1.245	1.255				1.247	1.249	1.682	1.692
1⅜	1 5/32	1.128	1.125	1.375	1.395	1⅞	2	1 27/64	1.373	1.375	1.875	1.895
		1.127	1.124	1.370	1.380				1.372	1.374	1.870	1.880
1½	1 5/32	1.128	1.125	1.500	1.520	1⅞	2	1 35/64	1.498	1.500	2.062	2.082
		1.127	1.124	1.495	1.505				1.497	1.499	2.057	2.067
1¾	1 27/64	1.378	1.375	1.750	1.770	2⅛	2¼	1 13/16	1.748	1.750	2.375	2.395
		1.377	1.374	1.745	1.755				1.747	1.749	2.370	2.380
2	1 35/64	1.504	1.500	2.000	2.020	2⅞	3	2 1/16	1.997	2.000	2.750	2.770
		1.503	1.498	1.995	2.005				1.996	1.998	2.745	2.755
2¼	1 13/16	1.754	1.750	2.250	2.270	2⅞	3	2 5/16	2.247	2.250	3.062	3.082
		1.753	1.748	2.245	2.255				2.246	2.248	3.057	3.067
2½	2 1/16	2.004	2.000	2.500	2.520	3⅜	3½	2 37/64	2.497	2.500	3.437	3.457
		2.003	1.998	2.495	2.505				2.496	2.498	3.432	3.442
2¾	2 5/16	2.254	2.250	2.750	2.770	3⅜	3½	2 55/64	2.747	2.750	3.750	3.770
		2.253	2.248	2.745	2.755				2.746	2.748	3.745	3.755
3	2 37/64	2.504	2.500	3.000	3.020	3⅞	4	3 3/32	2.997	3.000	4.125	4.145
		2.503	2.498	2.995	3.005				2.996	2.998	4.120	4.130
3½	2 55/64	2.754	2.750	3.500	3.520	4⅜	4½	3 39/64	3.497	3.500	4.750	4.770
		2.753	2.748	3.495	3.505				3.496	3.498	4.745	4.755
4	3 23/64	3.254	3.250	4.000	4.020	5⅜	5½	4⅛	3.997	4.000	5.500	5.520
		3.253	3.248	3.995	4.005				3.996	3.998	5.495	5.505

TEMPERING OF TOOL STEEL

The following table gives the temperature in degrees Fahrenheit necessary to produce the required color, when tempering hardened steel:

Lathe, Shaper and Planer Tools:
430°—Very light straw color.
450°—Light straw color.

Taps, Dies, and Wood Turning Tools:
470°—Dark straw color.
490°—Very dark straw color.

Hatchets, Chisels, etc.:
500°—Brownish yellow.
520°—Yellow tinged with purple.
530°—Light purple.

Springs, etc.,
550°—Dark purple.
570°—Dark blue.

Proportional parts of lead to one pound of pure block tin, which when melted will have the temperature in degrees Fahrenheit necessary to produce the required color on hardened steel, by simple immersion:

COLOR	Temperature	Pounds of Lead to One of Tin
Very light straw color	430°	1¾ lbs. to 1 lb. Tin
Light straw color	450°	2⅛ lbs. to 1 lb. Tin
Dark straw color	470°	2½ lbs. to 1 lb. Tin
Very dark straw color	490°	3½ lbs. to 1 lb. Tin
Brownish yellow	500°	4¾ lbs. to 1 lb. Tin
Light purple	530°	7½ lbs. to 1 lb. Tin
Dark purple	550°	12 lbs. to 1 lb. Tin
Dark blue	570°	25 lbs. to 1 lb. Tin

CASE HARDENING WROUGHT IRON

This process gives to wrought iron, a surface having the properties of steel, and parts subjected to friction are enabled to withstand considerably more wear. The depth to which the hardening may extend is from 1/16 to 1/8 inch. To case-harden, the polished surface is heated to a cherry red and then placed in a mixture of charcoal and soda ash, or ferro-cyanide of potassium and pieces of leather.

PREVENTION OF RUSTING IN OF SCREWS

The screws in machines exposed to heat and moist air soon rust in, even if oil is used, which makes the taking apart of a machine a difficult task. By dipping the screws before putting them in place in a thin paste of graphite and oil, they can be removed without difficulty, even after being in use for several years.

POUND RIVETS

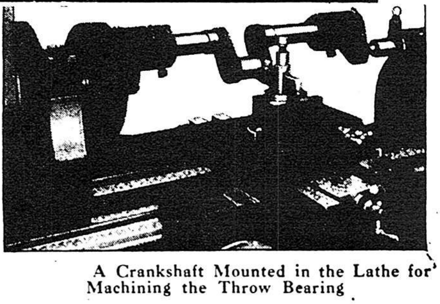
(Flat Head)

IN STOCK IN 200 POUND KEGS

Size Weight per M	Dimen.		Pr. per lb.	Size Weight per M	Dimen.		Pr. per lb.	Size Weight per M	Dimen.		Pr. per lb.
	Dia.	L'gth			Dia.	L'gth			Dia.	L'gth	
2 lbs.	.140	17/64	28	6 lbs.	.200	25/64	20	10 lbs.	.233	15/32	19
2½ "	.147	9/32	25	7 "	.215	13/32	20	12 "	.253	½	17
3 "	.160	5/16	24	8 "	.225	7/16	20	14 "	.275	33/64	17
4 "	.173	11/32	22	9 "	.230	29/64	19	16 "	.293	17/32	17
5 "	.185	3/8	21								

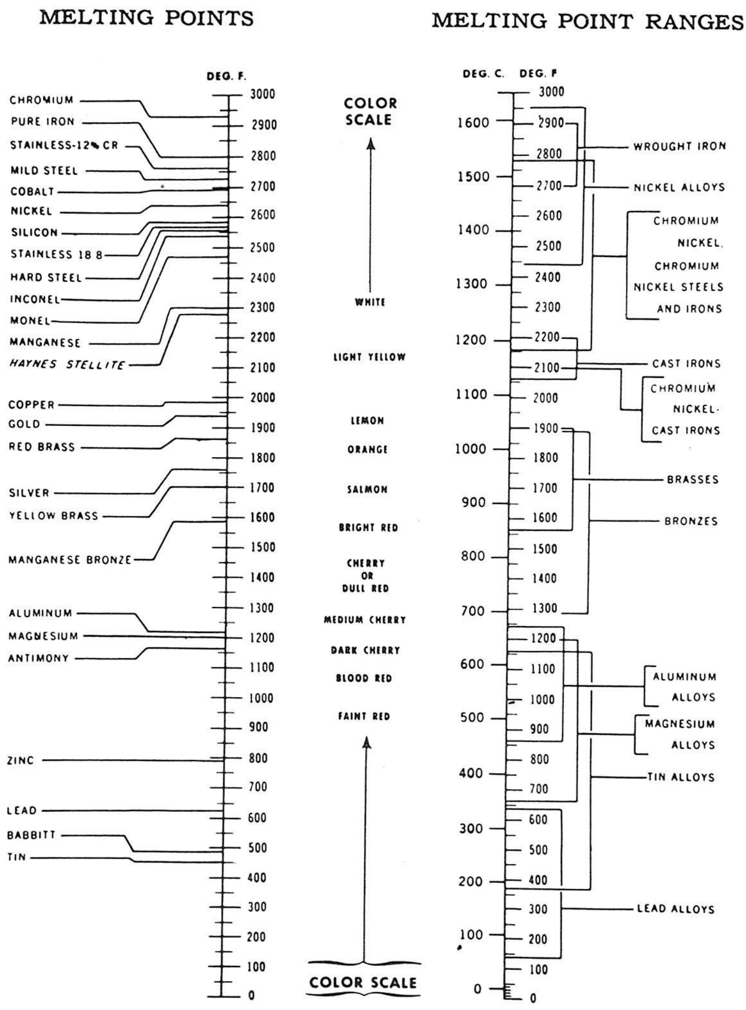
Crankshaft Turning

Crankshaft turning is an adaptation of eccentric machining. A single throw crankshaft mounted in the lathe for machining the throw bearing is shown in Fig. The adapters attached to each end of the crankshaft have offset center holes corresponding to the throw of the crankshaft.



A Crankshaft Mounted in the Lathe for Machining the Throw Bearing

MELTING POINTS AND COLOR SCALE



BRIDGEPORT BRASS COMPANY

Testing Crankshafts

Crankshafts may be tested between the lathe centers, as shown in Fig. 1 The dial indicator mounted in the tool post of the lathe reads in thousandths of an inch and will show exactly how much the crankshaft is sprung and will also disclose any out-of-round condition of the bearing. Straightening a crankshaft is a delicate job and should be attempted only by an experienced mechanic.

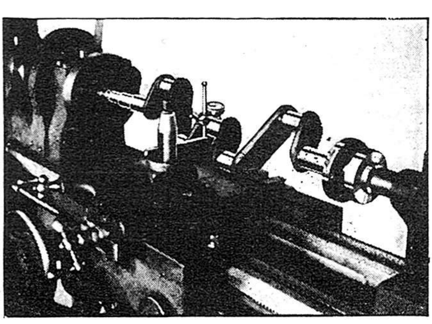


Fig. 1. Testing a Crankshaft in the Lathe

COLOR AND TEMPERATURE IN HEATING STEEL

THE average blacksmith and repair shop is not equipped with pyrometers with which to accurately determine the heat temperature of iron or steel. They have to depend upon the human eye, and in vision the idea of color frequently varies, but for all practical purposes color can be used as a fairly accurate gauge in heating and tempering steel.

Solid bodies which are heated to a point so that they glow with the intensity of their own heat will emit certain colors, depending on the temperature and this independently of the nature of the heated material. In other words, a piece of iron or steel heated to 1500 degrees F., will have practically the same brightness and color as a piece of firebrick which has been heated to the same temperature.

Consequently, providing that the eye of the individual and his keenness of vision are true, the following table will enable the mechanic who has not a pyrometer to determine approximately the temperatures of iron or steel from the following colors:

Color	Approximate Temperature Deg. Fahr.
Lowest red visible in the dark	800
Lowest red visible in twilight	900
Lowest red visible in daylight	950
Faint red	1000
Blood, medium	1050
Dull red	1100
Dark cherry red	1250
Full cherry red	1300
Bright cherry red	1450
Salmon	1550
Light red	1600
Dark orange	1625
Orange	1700
Full yellow	1800
Lemon	1900
Light yellow	2250
White	2400
Brilliant white	2600
Dazzling (blueish) white	2800

When the temperature is too low for the material to glow — as in tempering — it is sometimes possible to estimate it by placing a piece of polished steel at a point where it can come approximately to the temperature of the article to be determined upon. After taking the steel away it will be found to have a "temper" color corresponding to the highest temperature reached by it. These colors for the various temperatures are given below and are only for the range between 430 deg. and 600 deg. F.

Color	Temperature Deg. Fahr.
Very pale yellow	430
Light yellow	440
Pale straw yellow	450
Straw yellow	460
Deep straw yellow	470
Dark yellow	480
Yellow brown	490
Brown yellow	500
Spotted red yellow	510
Brown purple	520
Light purple	530
Full purple	540
Dark purple	550
Full blue	560
Dark blue	570
Very dark blue	600

From the foregoing table on high heats it is possible to consider the heating and cooling cycles of 0.20 per cent carbon steel, for example. This is about the average carbon content of the steel most widely encountered in the trade.

Refer to the heat colors in the above chart, and you can then determine the temperatures at which the changes take place in the composition of the steel due to the heat or cooling applied. By this means you can make heat treatment closely accurate in the blacksmith shop.

Stress Relieving, 1150 deg. F. — Around this temperature, there is no change in grain size or composition of the steel. But there is a change in

COLOR AND TEMPERATURE (Continued)

grain structure resulting in plastic flow of the material. In this manner, any internal stresses induced by welding are to all intents and purposes nullified. But if the material has received a permanent set after welding, stress relieving will not return it to normal.

The material should be held at this temperature for an hour per inch thickness. Cooling in still air is recommended.

Critical Temperature, 1330 deg. F. —No change in grain size of steel but change in composition starts. Iron carbides begin to dissolve and austentic iron makes its appearance. Below this temperature, quenching has no effect on hardness. Above this temperature, quenching increases the hardness but lowers the ductility of the steel.

Critical Temperature, 1520 deg. F. — At this high-critical temperature, full austentic iron is obtained. Quick cooling just above this temperature results in a fine grained, hardened steel. As the temperature increases, however, grain growth begins and quenching results in large coarse grains with a corresponding loss in ductility. For welds in this state subsequent annealing is strongly recommended.

Hardened steels may be tempered by reheating to a temperature just below the critical range and followed by a convenient rate of cooling.

Top Annealing Temperature, 1625 deg. F. — For full annealing, the steel should be held around this temperature for one hour per inch of thickness and cooled very slowly in the furnace or in some medium such as lime that will prolong the rate of cooling as compared to that of air.

Top Quenching in Water, 1640 deg. F. — Above this temperature (a dark orange), the steel should be quenched in oil or lead.

Top Normalizing Temperature, 1770 deg. F. — The steel is heated at this temperature and cooled in still air at ordinary temperatures. The steel is thus given a grain of known structure, size and composition. Normalizing is always followed by some desired heat treatment.

Top Forging Temperature, 2380 deg. F. — Above this temperature, the steel should not be forged.

At 2710 deg. F. liquid iron appears in the steel, and at 2770 deg. F., iron becomes completely liquid.

Melting Points of Metals

Some metals seem to melt more easily than others, which I presume means they melt at lower temperatures. Where can I obtain a table showing the approximate melting points of the principal metals used in welding?

As this is a subject of general interest we have compiled such a table and it is given below. It must be remembered, however, that pure metals melt at the temperature given, whereas alloys, that is combinations of 2 or more metals, have a melting range, and not a single melting temperature.

By a melting range we mean that there may be a difference of 10 or 15 or even more degrees during which some of the crystals of the alloy are molten, while others still remain solid or in a plastic condition. As the temperature increases finally the whole mass becomes molten.

MELTING POINTS (Approximate, of Pure Metals and Alloys)

	Degrees F.
Iron (Pure)	2786
Steel (Mild) (Alloy)	2700
Nickel (Pure)	2646
Steel (Medium Carbon) (Alloy)	2600
Steel (High Carbon) (Alloy)	2500
Monel Metal (Alloy)	2480
Iron (Cast) (Alloy)	2300
Iron (Malleable) (Alloy)	2300

MELTING POINTS (Continued)

Copper (Pure)	1981
Bronze (Phosphor) (Alloy)	1922
Brass (Common Yellow) (Alloy)	1652
Bronze (Tobin) (Alloy)	1625
Silver Brazing Alloys	1175 to 1600
Aluminum (Pure)	1218
Aluminum (Cast) (8% Copper) (Alloy)	1175
Aluminum (5% silicon) (Alloy)	1117
Antimony (Pure)	1166
Zinc (Pure)	786
Babbitt (Alloy)	500 to 700
Lead (Pure)	620
Solder (Alloy)	350 to 550
Tin (Pure)	450

Blow Holes In Cast Iron

What causes the molten metal in welding cast iron to be full of blow holes? When I first start to make a weld in a casting I seem to get along fairly well, but the puddle soon develops a lot of blow holes, which I cannot get rid of. Is the trouble with the rod, or flux?

The reason why you do not have difficulty when the metal is first molten is because the metal is hot enough to melt, but not too hot to produce gas. If the puddle of molten metal is overheated certain constituents are burned producing gases, which will bubble from the molten iron. In other words, the puddle will "boil" as it is often called. If the molten metal is allowed to cool quickly the gas is entrapped as the metal solidifies and "blow holes" result.

To avoid this condition it is only necessary to heat the puddle to a lower temperature. This can be done by using a smaller tip, or preferably by reducing the pressure of the two gases, oxygen and acetylene to prevent what is sometimes called a "blowing" or harsh flame. Some welders get into the habit of using too large a torch for the job and sometimes they turn the pressures up too high for a soft neutral flame at the tip. When this is done a casting, or any other job, which is being welded is likely to be overheated. Perhaps one of the difficulties lies in trying to heat a casting too rapidly and failing to preheat the casting before starting to weld.

Cast iron should be heated very slowly and if the casting is of any size it should be protected by fire brick, asbestos, or other means during heating and the heat should be slowly applied until the casting has reached a dull red heat.

When the torch is used, with a properly adjusted flame, the puddle may be kept just hot enough, but not too hot. Good rods and fluxes are of course essential, but ordinarily blow holes are not caused by these, but are the result of too much heat, as described above. We would suggest that you take a scrap casting and experiment with these thoughts in mind. We believe you will solve the trouble.

Difference Between Sheet and Cast Aluminum — Method of Welding Each

Cast Aluminum is usually an alloy of Approx. 8% copper and the balance aluminum. In some instances a small amount of zinc is added. Approx. melting point is 1175 F.

Aluminum Sheets (for tanks, etc.) are usually Pure Aluminum. Melting point Approx. 1215 F.

Cast Aluminum is ordinarily welded with a cast aluminum flux and cast aluminum welding rods made of the same alloy. Some preheating is usually necessary and can be done with city or natural gas burner without air. Care must be exercised to avoid overheating, and casting well supported to prevent warping.

Aluminum Sheets (pure aluminum) is usually welded with pure aluminum welding rod and a good sheet-aluminum flux. Very thin sheets may be flanged (edges bent at right angle to sheet) and flanges held securely together in a jig. Flux may be pasted on the seam and flanges melted down to make the weld. In this case, welding rod is not required except at start — or to repair hole accidently melted in the metal.

RYERSON COLOR MARKS FOR STAINLESS STEEL

Grade	Type No.	Color Mark	Grade	Type No.	Color Mark
18-8	302	Yellow	18-8-M	316	Purple
18-8-EZ	303	Black	18-8M Spec.	317	Orange
18-8-S	304	Green	18-8-C	347	Pink
25-12	309	Brown	12-EZ	416	Blue
25-20	310	Red			

HEAT TREATMENTS FOR CARBON AND ALLOY STEELS—1

(Recommended for various steels conforming to S. A. E. specifications)

Heat Treatment A

After forging or machining:

1. Carbonize between 1600° F. and 1750° F. (1650°–1700° F. desired).
2. Cool slowly or quench.
3. Reheat to 1450°–1500° F. and quench.

Heat Treatment B

After forging or machining:

1. Carbonize between 1600° F. and 1750° F. (1650°–1700° F. desired).
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1550°–1625° F.
4. Quench.
5. Reheat to 1400°–1450° F.
6. Quench.
7. Draw in hot oil varying from 300°–450° F., depending upon hardness desired.

Heat Treatment D

After forging or machining:

1. Heat to 1500°–1600° F.
2. Quench.
3. Reheat to 1450°–1500° F.
4. Quench.
5. Reheat to 600°–1200° F. and cool slowly.

Heat Treatment E

After forging or machining:

1. Heat to 1500°–1550° F.
2. Cool slowly.
3. Reheat to 1450°–1500° F.
4. Quench.
5. Reheat to 600°–1200° F. and cool slowly.

Heat Treatment F

After shaping or coiling:

1. Heat to 1425°–1475° F.
2. Quench in oil.
3. Reheat to 400°–900° F., according to temper desired, and cool slowly.

Heat Treatment G

After forging or machining:

1. Carbonize between 1600° F. and 1750° F. (1650°–1700° F. desired).
2. Cool slowly in the carbonizing material.
3. Reheat to 1500°–1550° F.
4. Quench.
5. Reheat to 1300°–1400° F.
6. Quench.
7. Reheat to 250°–500° F. (depending upon work) and cool slowly.

Heat Treatment H

After forging or machining:

1. Heat to 1500°–1600° F.
2. Quench.
3. Reheat to 600°–1200° F. and cool slowly.

Heat Treatment K

After forging or machining:

1. Heat to 1500°–1550° F.
2. Quench.
3. Reheat to 1300°–1400° F.
4. Quench.
5. Reheat to 600°–1200° F. and cool slowly.

Heat Treatment L

After forging or machining:

1. Carbonize at a temperature between 1600° F. and 1750° F. (1650°–1700° F. desired).
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1400°–1500° F.
4. Quench.
5. Reheat to 1300°–1400° F.
6. Quench.
7. Reheat to 250°–500° F. and cool slowly.

Heat Treatment M

After forging or machining:

1. Heat to 1450°–1500° F.
2. Quench.
3. Reheat to 500°–1250° F. and cool slowly.

HEAT TREATMENTS FOR CARBON AND ALLOY STEELS—2

(Recommended for Various Steels conforming to S. A. E. specifications)

Heat Treatment P

After forging or machining:

1. Heat to 1450°–1500° F.
2. Quench.
3. Reheat to 1375°–1450° F.
4. Quench.
5. Reheat to 500°–1250° F. and cool slowly.

Heat Treatment Q

After forging:

1. Heat to 1475°–1525° F. (Hold at this temperature one-half hour to insure thorough heating.)
2. Cool slowly.
3. Machine.
4. Reheat to 1375°–1425° F.
5. Quench.
6. Reheat to 250°–550° F. and cool slowly.

Heat Treatment R

After forging:

1. Heat to 1500°–1550° F.
2. Quench in oil
3. Reheat to 1200°–1300° F. (Hold at this temperature three hours.)
4. Cool slowly.
5. Machine.
6. Reheat to 1350°-1450° F.
7. Quench in oil.
8. Reheat to 250°-500° F. and cool slowly.

Heat Treatment S

After forging or machining:

1. Carbonize at a temperature between 1600° F. and 1750° F (1650°–1700° F. desired).
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1650°–1750° F.
4. Quench.
5. Reheat to 1475°–1550° F.
6. Quench.
7. Reheat to 250°–550° F. and cool slowly.

Heat Treatment T

After forging or machining:

1. Heat to 1650°–1750° F.
2. Quench.
3. Reheat to 500°–1300° F. and cool slowly.

Heat Treatment U

After forging:

1. Heat to 1525°–1600° F. (Hold for about one-half hour.)
2. Cool slowly.
3. Machine.
4. Reheat to 1650°–1700° F.
5. Quench.
6. Reheat to 350°–550° F. and cool slowly.

Heat Treatment V

After forging or machining:

1. Heat to 1650°–1750° F.
2. Quench.
3. Reheat to 400°–1200° F. and cool slowly.

DRILL ROD

Standard Tolerances for Size

ROUNDS

1.500" to .500"	.001" + or –
.499" to .125"	.0005" + or –
.124" and smaller	.0003" + or –

FLATS, SQUARES, HEXAGONS, OCTAGONS

1" to 3/4"	.0015" + or –
11/16" to 1/4"	.001" + or –
Smaller than 1/4"	.0005" + or –

COLD ROLLED LOW CARBON SHEETS AND STRIP

Rockwell B	Brinell	Shore Scleroscope	Rockwell B	Brinell	Shore Scleroscope
100	216	40	65	106	20
95	186	35	60	98	19
90	163	30	55	91	18
85	147	28	50	84	16
80	134	26	45	78	15
75	124	24	40	71	14
70	115	22	35	65	14

Molybdenum Steels

S. A. E. No.	Carbon Range	Manganese Range	Phosphorus, Max.	Sulfur, Max.	Chromium Range	Nickel Range	Molybdenum Range
4130	0.25–0.35	0.50–0.80	0.040	0.050	0.50–0.80	.....	0.15–0.25
X4130	0.25–0.35	0.40–0.60	0.040	0.050	0.80–1.10	.....	0.15–0.25
4135	0.30–0.40	0.60–0.90	0.040	0.050	0.80–1.10	.....	0.15–0.25
4140	0.35–0.45	0.60–0.90	0.040	0.050	0.80–1.10	.....	0.15–0.25
4150	0.45–0.55	0.60–0.90	0.040	0.050	0.80–1.10	.....	0.15–0.25
4320	0.15–0.25	0.40–0.70	0.040	0.050	0.30–0.60	1.65–2.00	0.20–0.30
4340	0.35–0.45	0.50–0.80	0.040	0.050	0.50–0.80	1.50–2.00	0.30–0.40
X4340	0.35–0.45	0.50–0.80	0.040	0.050	0.60–0.90	1.50–2.00	0.20–0.30
4615	0.10–0.20	0.40–0.70	0.040	0.050	.....	1.65–2.00	0.20–0.30
4620	0.15–0.25	0.40–0.70	0.040	0.050	.....	1.65–2.00	0.20–0.30
4640	0.35–0.45	0.50–0.80	0.040	0.050	.....	1.65–2.00	0.20–0.30
4815	0.10–0.20	0.40–0.60	0.040	0.050	.....	3.25–3.75	0.20–0.30
4820	0.15–0.25	0.40–0.60	0.040	0.050	.....	3.25–3.75	0.20–0.30

[1]Silicon range of all S. A. E. basic open hearth alloy steels shall be 0.15–0.30. For electric and acid open hearth alloy steels, the silicon content shall be 0.15 minimum.

Silicon Manganese Steels

S. A. E. No.	Carbon Range	Manganese Range	Phosphorus, Max.	Sulfur, Max.	Silicon Range
9255	0.50–0.60	0.60–0.90	0.040	0.050	1.80–2.20
9260	0.55–0.65	0.60–0.90	0.040	0.050	1.80–2.20

Corrosion and Heat Resisting Alloys

S. A. E. No.	Carbon, Max.	Manganese, Max.	Silicon, Max.	Phosphorus, Max.	Sulfur, Max.	Chromium Range	Nickel Range
30905	0.08	0.20–0.70	0.75	0.030	0.030	17.00–20.00	8.00–10.00
30915	0.09–0.20	0.20–0.70	0.75	0.030	0.030	17.00–20.00	8.00–10.00
51210	0.12	0.60	0.50	0.030	0.030	11.50–13.00	....
X51410	0.12	0.60	0.50	0.030	0.15–0.50	13.00–15.00	....
51335	0.25–0.40	0.60	0.50	0.030	0.030	12.00–14.00	....
51510	0.12	0.60	0.50	0.030	0.030	14.00–16.00	....
51710	0.12	0.60	0.50	0.030	0.030	16.00–18.00	....

[1]Silicon range of all S. A. E. basic open hearth alloy steels shall be 0.15–0.30. For electric and acid open hearth alloy steels, the silicon content shall be 0.15 minimum.

Free Cutting Steels

S.A.E. No.	Carbon Range	Manganese Range	Phosphorus Range	Sulfur Range
1112	0.08–0.16	0.60–0.90	0.09–0.13	0.10 –0.20
X1112	0.08–0.16	0.60–0.90	0.09–0.13	0.20 –0.30
1115	0.10–0.20	0.70–1.00	0.045 max.	0.075–0.15
1120	0.15–0.25	0.60–0.90	0.045 max.	0.075–0.15
X1314	0.10–0.20	1.00–1.30	0.045 max.	0.075–0.15
X1315	0.10–0.20	1.30–1.60	0.045 max.	0.075–0.15
X1330	0.25–0.35	1.35–1.65	0.045 max.	0.075–0.15
X1335	0.30–0.40	1.35–1.65	0.045 max.	0.075–0.15
X1340	0.35–0.45	1.35–1.65	0.045 max.	0.075–0.15

Manganese Steels[1]

S. A. E. No.	Carbon Range	Manganese Range	Phosphorus, Max.	Sulfur, Max.
T1330	0.25–0.35	1.60–1.90	0.040	0.050
T1335	0.30–0.40	1.60–1.90	0.040	0.050
T1340	0.35–0.45	1.60–1.90	0.040	0.050
T1345	0.40–0.50	1.60–1.90	0.040	0.050
T1350	0.45–0.55	1.60–1.90	0.040	0.050

To Soften Cast-Iron for Drilling—Heat to a cherry red, having it lay level in the fire, Then with tongs, put on a piece of brimstone, a little less in size than the hole is to be. This softens the iron entirely through. Let it lie in the fire until slightly cooled, when it is ready to drill.

S. A. E. STANDARD SPECIFICATIONS

Nickel-Chromium Steels

S. A. E. Steel No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.	Nickel Range	Chromium Range
3115	0.10–0.20	0.30–0.60	0.04	0.05	1.00–1.50	0.45–0.75
3120	0.15–0.25	0.30–0.60	0.04	0.05	1.00–1.50	0.45–0.75
3125	0.20–0.30	0.50–0.80	0.04	0.05	1.00–1.50	0.45–0.75
3130	0.25–0.35	0.50–0.80	0.04	0.05	1.00–1.50	0.45–0.75
3135	0.30–0.40	0.50–0.80	0.04	0.05	1.00–1.50	0.45–0.75
3140	0.35–0.45	0.50–0.80	0.04	0.05	1.00–1.50	0.45–0.75
3145	0.40–0.50	0.50–0.80	0.04	0.05	1.00–1.50	0.45–0.75
3150	0.45–0.55	0.50–0.80	0.04	0.05	1.00–1.50	0.45–0.75
3215	0.10–0.20	0.30–0.60	0.04	0.045	1.50–2.00	0.90–1.25
3220	0.15–0.25	0.30–0.60	0.04	0.045	1.50–2.00	0.90–1.25
3230	0.25–0.35	0.30–0.60	0.04	0.045	1.50–2.00	0.90–1.25
3240	0.35–0.45	0.30–0.60	0.04	0.045	1.50–2.00	0.90–1.25
3245	0.40–0.50	0.30–0.60	0.04	0.045	1.50–2.00	0.90–1.25
3250	0.45–0.55	0.30–0.60	0.04	0.045	1.50–2.00	0.90–1.25
3312	max. 0.17	0.30–0.60	0.04	0.045	3.25–3.75	1.25–1.75
3325	0.20–0.30	0.30–0.60	0.04	0.045	3.25–3.75	1.25–1.75
3335	0.30–0.40	0.30–0.60	0.04	0.045	3.25–3.75	1.25–1.75
3340	0.35–0.45	0.30–0.60	0.04	0.045	3.25–3.75	1.25–1.75
3415	0.10–0.20	0.30–0.60	0.04	0.045	2.75–3.25	0.60–0.95
3435	0.30–0.40	0.30–0.60	0.04	0.045	2.75–3.25	0.60–0.95
3450	0.45–0.55	0.30–0.60	0.04	0.045	2.75–3.25	0.60–0.95

Chromium Steels

S. A. E. Steel No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.	Chromium Range
5120	0.15–0.25	0.30–0.60	0.04	0.05	0.60–0.90
5140	0.35–0.45	0.50–0.80	0.04	0.05	0.80–1.10
5150	0.45–0.55	0.50–0.80	0.04	0.05	0.80–1.10
52100	0.95–1.10	0.20–0.50	0.03	0.035	1.20–1.50

Chromium - Vanadium Steels

S. A. E. Steel No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.	Chromium Range	Vanadium	
						Min.	Desired
6115	0.10–0.20	0.30–0.60	0.04	0.045	0.80–1.10	0.15	0.18
6120	0.15–0.25	0.30–0.60	0.04	0.045	0.80–1.10	0.15	0.18
6125	0.20–0.30	0.50–0.80	0.04	0.045	0.80–1.10	0.15	0.18
6130	0.25–0.35	0.50–0.80	0.04	0.045	0.80–1.10	0.15	0.18
6135	0.30–0.40	0.50–0.80	0.04	0.045	0.80–1.10	0.15	0.18
6140	0.35–0.45	0.50–0.80	0.04	0.045	0.80–1.10	0.15	0.18
6145	0.40–0.50	0.50–0.80	0.04	0.045	0.80–1.10	0.15	0.18
6150	0.45–0.55	0.50–0.80	0.04	0.045	0.80–1.10	0.15	0.18
6195	0.90–1.05	0.20–0.45	0.03	0.035	0.80–1.10	0.15	0.18

Tungsten Steels

S. A. E. Steel No.	Carbon Range	Manganese Max.	Phosphorus Max.	Sulphur Max.	Chromium Range	Tungsten Range
71360	0.50–0.70	0.30	0.035	0.035	3.00–4.00	12.00–15.00
71660	0.50–0.70	0.30	0.035	0.035	3.00–4.00	15.00–18.00
7260	0.50–0.70	0.30	0.035	0.035	0.50–1.00	1.50–2.00

S. A. E. STANDARD SPECIFICATIONS

Carbon Steels

S. A. E. Steel No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.
1010	0.05—0.15	0.30—0.60	0.045	0.055
1015	0.10—0.20	0.30—0.60	0.045	0.055
1020	0.15—0.25	0.30—0.60	0.045	0.055
O.H.1020–90	0.15—0.25	0.75—1.05	0.045	0.055
1025	0.20—0.30	0.50—0.80	0.045	0.055
1030	0.25—0.35	0.50—0.80	0.045	0.055
1035	0.30—0.40	0.50—0.80	0.045	0.055
1040	0.35—0.45	0.50—0.80	0.045	0.055
1045	0.40—0.50	0.50—0.80	0.045	0.055
1050	0.45—0.55	0.50—0.80	0.045	0.055
1095	0.90—1.05	0.25—0.50	0.040	0.050
X-1314	0.10—0.20	1.00—1.30	0.050	0.08—0.13
X-1315	0.10—0.20	1.25—1.55	0.050	0.08—0.13
1335	0.30—0.40	1.60—1.90	0.040	0.050
*1350	0.45—0.55	0.90—1.20	0.040	0.050
*1360	0.55—0.70	0.90—1.20	0.040	0.050

* Silicon not to exceed 0.30.

Screw Stocks

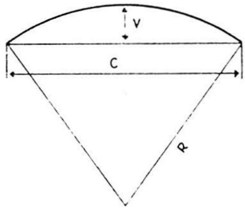
S. A. E. Steel No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.
1112	0.08—0.16	0.60—0.90	0.09—0.13	0.10 —0.18
1120	0.15—0.25	0.60—0.90	max. 0.06	0.075—0.15

Nickel Steels

S. A. E. Steel No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.	Nickel Range
2015	0.10–0.20	0.30–0.60	0.04	0.05	0.40–0.60
2115	0.10–0.20	0.30–0.60	0.04	0.05	1.25–1.75
2315	0.10–0.20	0.30–0.60	0.04	0.05	3.25–3.75
2320	0.15–0.25	0.30–0.60	0.04	0.05	3.25–3.75
2330	0.25–0.35	0.50–0.80	0.04	0.05	3.25–3.75
2335	0.30–0.40	0.50–0.80	0.04	0.05	3.25–3.75
2340	0.35–0.45	0.50–0.80	0.04	0.05	3.25–3.75
2345	0.40–0.50	0.50–0.80	0.04	0.05	3.25–3.75
2350	0.45–0.55	0.50–0.80	0.04	0.05	3.25–3.75
2512	max. 0.17	0.30–0.60	0.04	0.05	4.75–5.25

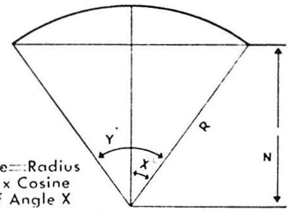
NOTES ON CORRUGATED SHEETS

To find the Rise when radius length of Span is given, use following formula:



$$V = R - \sqrt{R^2 - \frac{C^2}{4}} \text{ or nearly } \frac{C^2}{8R}$$

To find the Rise when radius and length of Arc is given, use following formula:



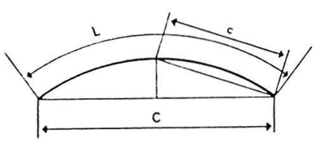
Rise=Radius
R x Cosine
of Angle X

$$Y = \frac{\text{Arc} \times 360^\circ}{\text{Cir. of Circle}}$$

$$\frac{Z}{R} = \text{Cosine of Angle X}$$

$$X = \frac{Y}{2}$$

$$Z = R \times \text{Cosine X}$$



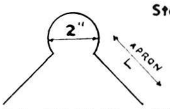
To find length of Arc when Span and Small Chord are given:

L—Length of Arc
C—Span
c—Small Chord

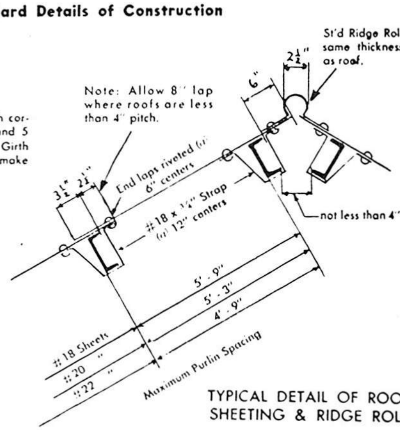
$$L = \frac{8c - C}{3}$$

CORRUGATED SHEET DATA

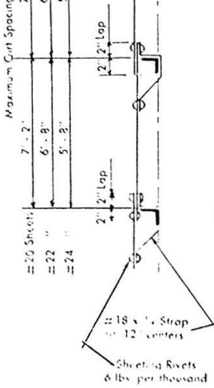
Standard Details of Construction



Girths of 8", 10", 12" and 14", with corresponding Apron "L" of 2, 3, 4 and 5 inches. Diameter of roll, 2 inches. Girth is full width of sheet required to make ridge roll.

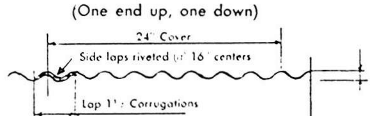


TYPICAL DETAIL OF ROOF SHEETING & RIDGE ROLL



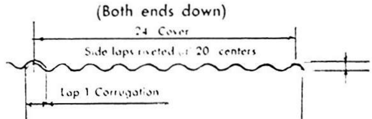
SIDING DETAIL

(One end up, one down)



Roofing Sheet—Rolled from 30" flat sheet

(Both ends down)



Siding Sheet—Rolled from 28" flat sheet

NOTES ON CORRUGATED SHEETS—(Cont'd)

SAFE LOADS—PER SHEET

Supported at Ends Only. Sheets, 26 Inches Wide

	Gauge	28	27	26	24	22	20	18	16
2½" Corrugations	6'0" Span..	88	97	106	141	176	211	282	352
	7'0" Span..	75	83	91	121	151	181	242	302
	8'0" Span..	66	73	79	106	132	158	211	264
	9'0" Span..	59	65	70	94	117	141	188	235
	10'0" Span..	53	58	63	85	106	127	169	211
1¼" Corrugations	6'0" Span..	53	58	63	85	106	127	169	211
	7'0" Span..	45	50	55	73	91	109	145	181
	8'0" Span..	40	44	47	64	79	95	127	158
	9'0" Span..	35	39	42	56	70	85	113	141
	10'0" Span..	32	34	38	51	64	76	101	127

⅝ inch is taken as depth of 2½ inch corrugations, ⅜ inch as depth of 1¼ inch corrugations.

The following formula has been used: $W = \frac{99900\ t\ b\ d}{L}$

L = Supported length of sheet in inches. t = Thickness of sheet in inches. b = Width of sheet in inches. d = Depth of corrugations in inches.

W = Breaking weight distributed in pounds. $\frac{W}{4}$ = Safe loads per sheet between supports.

CORRUGATED SHEETS

TO ASCERTAIN LENGTH OF A CURVED SHEET BY THE FOLLOWING TABLE

RULE.—Divide height (or size) by base (or span), find quotient in column of heights, take length for that height opposite to it in next column on the right hand. Multiply length thus obtained by base (or span) and product will give length of sheet.

EXAMPLE.—Find length of sheet, base (or span) being 100 inches, rise being 25 inches.

25 divided by 100 equals .25; and .25, per table, equals 1.15912, length of base, which multiplied by 100 equals 115.912 inches, length of sheet before curving.

TABLE FOR COMPUTING LENGTHS OF CURVED SHEETS

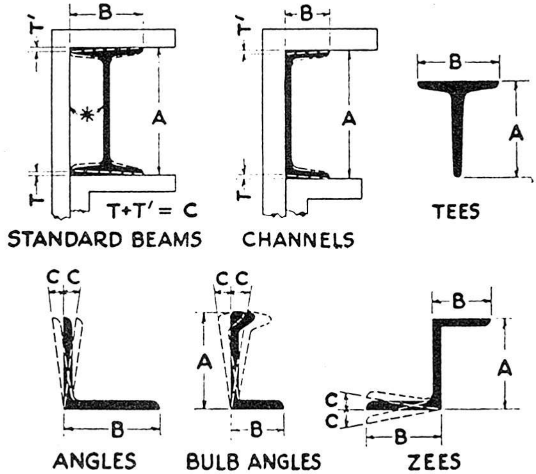
Height	Length	Height	Length	Height	Length	Height	Length
.001	1.00002	.128	1.04313	.176	1.08066	.224	1.12885
.005	1.00007	.129	1.0438	.177	1.08156	.225	1.12997
.01	1.00027	.13	1.04447	.178	1.08246	.226	1.13108
.015	1.00061	.131	1.04515	.179	1.08337	.227	1.13219
.02	1.00107	.132	1.04584	.18	1.08428	.228	1.13334
.025	1.00167	.133	1.04652	.181	1.08519	.229	1.13441
.03	1.0024	.134	1.04722	.182	1.08611	.23	1.13557
.035	1.00327	.135	1.04792	.183	1.08704	.231	1.13671
.04	1.00426	.136	1.04862	.184	1.08797	.232	1.13786
.045	1.00539	.137	1.04932	.185	1.0889	.233	1.13903
.05	1.00665	.138	1.05003	.186	1.08984	.234	1.1402
.055	1.00805	.139	1.05075	.187	1.09079	.235	1.14136
.06	1.00957	.14	1.05147	.188	1.09174	.236	1.14247
.065	1.01123	.141	1.0522	.189	1.09269	.237	1.14363
.07	1.01302	.142	1.05293	.19	1.09365	.238	1.1448
.075	1.01493	.143	1.05367	.191	1.09461	.239	1.14597
.08	1.01698	.144	1.05441	.192	1.09557	.24	1.14714
.085	1.01916	.145	1.05516	.193	1.09654	.241	1.14831
.09	1.02146	.146	1.05591	.194	1.09752	.242	1.14949
.095	1.02389	.147	1.05667	.195	1.0985	.243	1.15067
.1	1.02645	.148	1.05743	.196	1.09949	.244	1.15186
.101	1.02698	.149	1.05819	.197	1.10048	.245	1.15308
.102	1.02752	.15	1.05896	.198	1.10147	.246	1.15429
.103	1.02806	.151	1.05973	.199	1.10247	.247	1.15549
.104	1.0286	.152	1.06051	.2	1.10348	.248	1.1567
.105	1.02914	.153	1.0613	.201	1.10447	.249	1.15791
.106	1.0297	.154	1.06209	.202	1.10548	.25	1.15912
.107	1.03026	.155	1.06288	.203	1.1065	.251	1.16033
.108	1.03082	.156	1.06368	.204	1.10752	.252	1.16157
.109	1.03139	.157	1.06449	.205	1.10855	.253	1.16279
.110	1.03196	.158	1.0653	.206	1.10958	.254	1.16402
.111	1.03254	.159	1.06611	.207	1.11062	.255	1.16526
.112	1.03312	.16	1.06693	.208	1.11165	.256	1.16649
.113	1.03371	.161	1.06775	.209	1.11269	.257	1.16774
.114	1.0343	.162	1.06858	.21	1.11374	.258	1.16899
.115	1.0399	.163	1.06941	.211	1.11479	.259	1.17024
.116	1.03551	.164	1.07025	.212	1.11584	.26	1.1715
.117	1.03611	.165	1.07109	.213	1.11692	.261	1.17275
.118	1.03672	.166	1.07194	.214	1.11796	.262	1.17401
.119	1.03734	.167	1.07279	.215	1.11904	.263	1.17527
.12	1.03797	.168	1.07365	.216	1.12011	.264	1.17655
.121	1.0386	.169	1.07451	.217	1.12118	.265	1.17784
.122	1.03923	.17	1.07537	.218	1.12225	.266	1.17912
.123	1.03987	.171	1.07624	.219	1.12334	.267	1.1804
.124	1.04051	.172	1.07711	.22	1.12445	.268	1.18162
.125	1.04116	.173	1.07799	.221	1.12556	.269	1.18294
.126	1.04181	.174	1.07888	.222	1.12663	.27	1.18428
.127	1.04247	.175	1.07977	.223	1.12774	.271	1.18557

TABLE FOR COMPUTING LENGTHS OF CURVED SHEETS—Continued

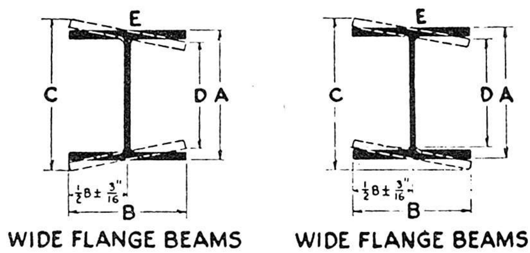
Height	Length	Height	Length	Height	Length	Height	Length
.272	1.18688	.33	1.26892	.387	1.36084	.444	1.46255
.273	1.18819	.331	1.27044	.388	1.36254	.445	1.46441
.274	1.18969	.332	1.27196	.389	1.36425	.446	1.46628
.275	1.19082	.333	1.27349	.39	1.36596	.447	1.46815
.276	1.19214	.334	1.27502	.391	1.36767	.448	1.47002
.277	1.19345	.335	1.27656	.392	1.36939	.449	1.47189
.278	1.19477	.336	1.2781	.393	1.37111	.45	1.47377
.279	1.1961	.337	1.27964	.394	1.37283	.451	1.47565
.28	1.19743	.338	1.28118	.395	1.37455	.452	1.47753
.281	1.19887	.339	1.28273	.396	1.37628	.453	1.47942
.282	1.20011	.34	1.28428	.397	1.37801	.454	1.48131
.283	1.20146	.341	1.28583	.398	1.37974	.455	1.4832
.284	1.20282	.342	1.28739	.399	1.38148	.456	1.48509
.285	1.20419	.343	1.28895	.4	1.38322	.457	1.48699
.286	1.20558	.344	1.29052	.401	1.38496	.458	1.48889
.287	1.20696	.345	1.29209	.402	1.38671	.459	1.49079
.288	1.20828	.346	1.29366	.403	1.38846	.46	1.49269
.289	1.20967	.347	1.29523	.404	1.39021	.461	1.4946
.29	1.21202	.348	1.29681	.405	1.39196	.462	1.49651
.291	1.21239	.349	1.29839	.406	1.39372	.463	1.49842
.292	1.21381	.35	1.29997	.407	1.39548	.464	1.50033
.293	1.2152	.351	1.30156	.408	1.39724	.465	1.50224
.294	1.21658	.352	1.30315	.409	1.399	.466	1.50416
.295	1.21794	.353	1.30474	.41	1.40077	.467	1.50608
.296	1.21926	.354	1.30634	.411	1.40254	.468	1.508
.297	1.22061	.355	1.30794	.412	1.40432	.469	1.50992
.298	1.22203	.356	1.30954	.413	1.4061	.47	1.51182
.299	1.22347	.357	1.31115	.414	1.40788	.471	1.51378
.3	1.22495	.358	1.31276	.415	1.40966	.472	1.51571
.301	1.22635	.359	1.31437	.416	1.41145	.473	1.51764
.302	1.22776	.36	1.31599	.417	1.41324	.474	1.51958
.303	1.22918	.361	1.31761	.418	1.41503	.475	1.52152
.304	1.23061	.362	1.31923	.419	1.41682	.476	1.52346
.305	1.23205	.363	1.32086	.42	1.41861	.477	1.52541
.306	1.23349	.364	1.32249	.421	1.42041	.478	1.52736
.307	1.23494	.365	1.32413	.422	1.42222	.479	1.52931
.308	1.23636	.366	1.32577	.423	1.42402	.48	1.53126
.309	1.2378	.367	1.32741	.424	1.42583	.481	1.53322
.31	1.23925	.368	1.32905	.425	1.42764	.482	1.53518
.311	1.2407	.369	1.33069	.426	1.42945	.483	1.53714
.312	1.24216	.37	1.33234	.427	1.43127	.484	1.5391
.313	1.2436	.371	1.33399	.428	1.43309	.485	1.54186
.314	1.24506	.372	1.33561	.429	1.43491	.486	1.54302
.315	1.24654	.373	1.3373	.43	1.43673	.487	1.54499
.316	1.24801	.374	1.33896	.431	1.43856	.488	1.54696
.317	1.24946	.375	1.34063	.432	1.44039	.489	1.54893
.318	1.25095	.376	1.34229	.433	1.44222	.49	1.5509
.319	1.25243	.377	1.34396	.434	1.44405	.491	1.55228
.32	1.25391	.378	1.34563	.435	1.44589	.492	1.55486
.321	1.25539	.379	1.34731	.436	1.44773	.493	1.55685
.322	1.25686	.38	1.34899	.437	1.44957	.494	1.55881
.323	1.25836	.381	1.35068	.438	1.45142	.495	1.56083
.324	1.25987	.382	1.35237	.439	1.45327	.496	1.56282
.325	1.26137	.383	1.35406	.44	1.45512	.497	1.56481
.326	1.26286	.384	1.35575	.441	1.45697	.498	1.5668
.327	1.26437	.385	1.35744	.442	1.45883	.499	1.56879
.328	1.26588	.386	1.35914	.443	1.46069	.5	1.57079
.329	1.2674						

MANUFACTURERS' STANDARD PRACTICE

Permissible Variations for Standard Structural Beams, Channels, Tees, Angles, Bulb Angles and Zees



Permissible Variations for Wide Flange Structural Sections



APPROXIMATE WEIGHTS OF BOILER TUBES

External Diameter Inches	Standard Thickness, Minimum B.W.G.	Standard Thickness, Minimum Inches	Nominal Weight per Ft. Lbs. For Estimating Purposes (ASME) Stand. Thickness	One Extra Gauge	Two Extra Gauges	Three Extra Gauges	Four Extra Gauges
1	13	.095	1.037	1.168	1.263	1.384	1.500
1 1/4	13	.095	1.328	1.502	1.628	1.793	1.951
1 1/2	13	.095	1.619	1.836	1.994	2.201	2.402
1 3/4	13	.095	1.910	2.169	2.360	2.610	2.854
2	13	.095	2.201	2.503	2.726	3.018	3.305
2 1/4	13	.095	2.492	2.837	3.092	3.427	3.756
2 1/2	12	.109	3.171	3.457	3.835	4.207	4.665
2 3/4	12	.109	3.504	3.823	4.244	4.658	5.169
3	12	.109	3.838	4.189	4.652	5.110	5.674
3 1/4	11	.120	4.555	5.061	5.561	6.179	6.697
3 1/2	11	.120	4.921	5.469	6.012	6.683	7.247
4	10	.134	6.286	6.915	7.693	8.347	9.336
4 1/2	10	.134	7.103	7.817	8.702	9.447	10.580
5	9	.148	8.720	9.711	10.550	11.810	12.730
6	7	.180	12.750	14.290	15.410	16.640	17.450

GALVANIZED AND STAINLESS STEEL GAUGES

Galvanized Sheets		Stainless Steel Sheets			
				Aver. Wt. per Sq. Ft. Lbs. for	
Galvanized Sheet Gauge	Wt. per Sq. Ft. Lbs.	Stainless Sheet Gauge	Approximate Decimal Parts of an inch	Chrome Iron Alloys	Chrome Nickel C.R. Alloys
8	7.0312	8	.171875	7.0813	7.2187
9	6.4062	9	.156250	6.4375	6.5625
10	5.7812	10	.140625	5.7937	5.9062
11	5.1562	11	.125000	5.1500	5.2500
12	4.5312	12	.109375	4.5063	4.5937
13	3.9062	13	.093750	3.8625	3.9375
14	3.2812	14	.078125	3.2187	3.2812
15	2.9687	15	.070312	2.8968	2.9531
16	2.6562	16	.062500	2.5750	2.6250
17	2.4062	17	.056250	2.3175	2.3625
18	2.1562	18	.050000	2.0600	2.1000
19	1.9062	19	.043750	1.8025	1.8375
20	1.6562	20	.037500	1.5450	1.5750
21	1.5312	21	.034375	1.4160	1.4437
22	1.4062	22	.031250	1.2875	1.3125
23	1.2812	23	.028125	1.1587	1.1813
24	1.1562	24	.025000	1.0300	1.0500
25	1.0312	25	.021875	.9013	.9187
26	.9062	26	.018750	.7725	.7875
27	.8437	27	.017187	.7081	.7218
28	.7812	28	.015625	.6438	.6562
29	.7187	29	.014062	.5794	.5906
30	.6562	30	.012500	.5150	.5250

The Galvanized Sheet Gauge, established by custom, is based on the United States Standard Gauge, each galvanized sheet gauge weight being 2.5 oz. per sq. ft. heavier than the gauge weight of the same United States Standard Gauge number, regardless of coating weights.

APPROXIMATE WEIGHTS OF VARIOUS METALS

To find the weight of various metals, multiply the contents in cubic inches by the number shown below; the result will be the approximate weight in pounds.

Iron	.27777	Brass	.3112	Tin	.26562
Steel	.28332	Lead	.41015	Aluminum	.09375
Copper	.32118	Zinc	.25318		

NOTES ON CORRUGATED SHEETS

NUMBER OF CORRUGATED SHEETS IN ONE SQUARE

(100 sq. ft.—no allowance for laps)

Length of Sheet, Inches	2½" Corrug. (Sheets 26" wide)	1¼" Corrug. (Sheets 25" wide)
60	9.231	9.600
72	7.692	8.000
84	6.593	6.857
96	5.769	6.000
108	5.128	5.333
120	4.616	4.800
144	3.846	4.000

NUMBER OF SQUARE FEET IN ONE CORRUGATED SHEET

(Standard Lengths)

Length of Sheet, Inches	2½" Corrug. (Sheets 26" wide)	1¼" Corrug. (Sheets 25" wide)
60	10.833	10.416
72	13.000	12.500
84	15.166	14.583
96	17.333	16.666
108	19.500	18.750
120	21.666	20.833
144	26.000	25.000

EXTRUDED BRONZE ANGLES

Size in Inches	Thickness in Inches	Decimal Equivalent	Approx. Weight Lbs. per Lin. Ft.
½ x ½	⅛	.125	.40
¾ x ¾	⅛	.125	.63
1 x 1	⅛	.125	.84
1 x 1	¼	.250	1.68
1¼ x 1¼	⅛	.125	1.09
1½ x 1½	⅛	.125	1.30
1½ x 1½	3/16	.1875	1.90
1½ x 1½	¼	.250	2.60
2 x 2	⅛	.125	1.78
2 x 2	¼	.250	3.40
2½ x 2½	¼	.250	4.37
3 x 3	¼	.250	5.30

ROUND SEAMLESS BRASS TUBING

Soft Temper

Listed by Stubs Gauges

Outside Diameter	Thickness Stubs Gauge	Decimal Equivalent in Inches	Approx. Weight Lbs. per Ft.
¼	16	.065	.139
¼	20	.035	.0871
5/16	16	.065	.186
5/16	19	.042	.101
5/16	20	.035	.112
5/16	22	.028	.090
⅜	16	.065	.233
⅜	18	.049	.185
⅜	19	.042	.162
⅜	20	.035	.138

SQUARE BRASS TUBING

Size in Inches	Thickness Stubs Gauge	Decimal Equivalent in Inches	Approx. Weight Lbs. per Ft.
¼	21	.032	.107
⅜		.040	.189
½		.040	.270
½	21	.032	.231
⅝	21	.032	.293
¾	21	.032	.355
1	21	.032	.478
1¼	21	.032	.603

COPPER TUBING

OPEN ENDS

Soft Temper

Outside Diameter	Thickness Stubs Gauge	Decimal Equiv. in Inches	Lengths	Approx. Weight Lbs. per Ft.
7/16	22	.028	6 ft. straight	.144
½	22	.028	6 ft. straight	.165
¾	16	.065	50 ft. coils	.542
1	16	.065	50 ft. coils	.740

SPECIFIC GRAVITY—

The specific gravity of a substance is its weight as compared with the weight of an equal bulk of pure water.

For making specific gravity determinations the temperature of the water is usually taken at 62°F., when 1 cu. ft. of water weighs 62.355 lbs. Water is at its greatest density at 39.2°F. or 4° Centigrade.

MISCELLANEOUS.

IRON, LEAD, ETC.	BEEF, PORK, ETC.
14 pounds.......1 stone.	200 pounds.....1 barrel.
21½ stones.........1 pig.	196 lbs. (flour) 1 barrel.
8 pigs............1 fother.	100 lbs. (fish) 1 quintal.

Stubs' Gages

The difference between the Stubs' Iron Wire Gage and the Stubs' Steel Wire Gage should be borne constantly in mind, the first, commonly being known as the English Standard Wire or Birmingham Gage which designates the Stubs' soft wire sizes, and the second, being used in measuring drawn steel wire or drill rods of Stubs' make.

STANDARD GAUGES AND WEIGHTS OF TIN PLATE

Approx. U. S. S. Gauge	Trade Term	Weight in Pounds Per Sq. Ft.	Base Weight	Approximate Thickness in Inches
38		.253	55	.0061
37		.276	60	.0068
36		.298	65	.0073
35		.321	70	.0079
34		.344	75	.0084
33		.367	80	.0090
32		.390	85	.0095
31		.413	90	.0101
31		.436	95	.0107
30½	I.C.L.	.459	100	.0113
30	I.C.	.491	107	.0120
29½		.528	115	
29		.542	118	.0133
29		.564	123	.0138
28	I.X.L.	.588	128	.0144
28	I.X.	.620	135	.0152
28	D.C.	.638	139	.0156
28½		.666	145	
27	I.X.X.L.	.680	148	.0167
27		.688	150	.0169
27	I.X.X.	.712	155	.0175
26	I.X.X.X.L.	.771	168	.0189
26	I.X.X.X.	.804	175	.0197
25	D.X.	.827	180	.0203
25	I.X.X.X.X.L.	.863	188	.0211
25	I.X.X.X.X.	.895	195	.0220
25	I.X.X.X.X.X.L.	.955	208	.0238
25	D.X.X.	.964	210	.0241
25	I.X.X.X.X.X.	.987	215	.0246
24	I.X.X.X.X.X.X.L.	1.047	228	.0261
24	I.X.X.X.X.X.X.	1.079	235	.0269
24	D.X.X.X.	1.102	240	.0275
23	I.X.X.X.X.X.X.X.L.	1.139	248	.0284
23	I.X.X.X.X.X.X.X.	1.171	255	.0292
23	I.X.X.X.X.X.X.X.X.L.	1.231	268	.0307
23	D.X.X.X.X.	1.240	270	.0310
22	I.X.X.X.X.X.X.X.X.	1.263	275	.0315

DRAWN BRASS ANGLES

Size in Inches	B & S Gauge	Decimal Equivalent	Approx. Weight Lbs. per Lin. Ft.
½ x ½	18	.040	.147
¾ x ¾	14	.064	.402
¾ x ¾	18	.040	.220
1 x ¼	20	.032	.146
1 x 1	14	.064	.470
1 x 1	18	.040	.294

TEMPERATURE—

The following equation will be found convenient for transforming temperature from one system to another:

Let F = degrees Fahrenheit; C = degree Centigrade; R = degrees Reamur.

$$\frac{F-32}{180}=\frac{C}{100}=\frac{R}{80}$$

Properties of Structural Shapes

Standard I-Beams

Depth of Beam Inches	Weight, per Foot Pounds	Area of Section Sq. Ins.	Thickness of Web Inch	Width of Flange Inches
3	5.7	1.64	.170	2.330
3	6.5	1.88	.251	2.411
3	7.5	2.17	.349	2.509
4	7.7	2.21	.190	2.660
4	8.5	2.46	.253	2.723
4	9.5	2.76	.326	2.796
4	10.5	3.05	.400	2.870
5	10.0	2.87	.210	3.000
5	12.25	3.56	.347	3.137
5	14.75	4.29	.494	3.284
6	12.5	3.61	.230	3.330
6	14.75	4.29	.343	3.443
6	17.25	5.02	.465	3.565
7	15.3	4.43	.250	3.660
7	17.5	5.09	.345	3.755
7	20.0	5.83	.450	3.860
8	18.4	5.34	.270	4.000
8	20.5	5.97	.349	4.079
8	23.0	6.71	.441	4.171
8	25.5	7.43	.532	4.262
10	25.4	7.38	.310	4.660
10	30.0	8.75	.447	4.797
10	35.0	10.22	.594	4.944
10	40.0	11.69	.741	5.091
12	31.8	9.26	.350	5.000
12	35.0	10.20	.428	5.078
12	40.8	11.84	.460	5.250
12	45.0	13.10	.565	5.355
12	50.0	14.57	.687	5.477
12	55.0	16.04	.810	5.600
15	42.9	12.49	.410	5.500
15	45.0	13.12	.452	5.542
15	50.0	14.59	.550	5.640
15	55.0	16.06	.648	5.738
15	60.8	17.68	.590	6.000
15	65.0	18.91	.672	6.082
15	70.0	20.38	.770	6.180
15	75.0	21.85	.868	6.278
18	54.7	15.94	.460	6.000
18	60.0	17.50	.547	6.087
18	65.0	18.98	.629	6.169
18	70.0	20.46	.711	6.251
20	81.4	23.74	.600	7.000
20	85.0	24.80	.653	7.053
20	90.0	26.26	.726	7.126
20	95.0	27.74	.800	7.200
20	100.0	29.20	.873	7.273
24	79.9	23.33	.500	7.000
24	85.0	24.84	.563	7.063
24	90.0	26.30	.624	7.124
24	95.0	27.79	.686	7.186
24	100.0	29.25	.747	7.247
24	105.9	30.98	.625	7.875
24	110.0	32.18	.675	7.925
24	115.0	33.67	.737	7.987
24	120.0	35.13	.798	8.048

Standard Channels

Depth of Beam Inches	Weight, per Foot Pounds	Area of Section Sq. Ins.	Thickness of Web Inch	Width of Flange Inches
3	4.1	1.19	.170	1.410
3	5.0	1.46	.258	1.498
3	6.0	1.75	.356	1.596
4	5.4	1.56	.180	1.580
4	6.25	1.82	.247	1.647
4	7.25	2.12	.320	1.720
5	6.7	1.95	.190	1.750
5	9.0	2.63	.325	1.885
5	11.5	3.36	.472	2.032
6	8.2	2.39	.200	1.920
6	10.5	3.07	.314	2.034
6	13.0	3.81	.437	2.157
6	15.5	4.54	.559	2.279
7	9.8	2.85	.210	2.090
7	12.25	3.58	.314	2.194
7	14.75	4.32	.419	2.299
7	17.25	5.05	.524	2.404
7	19.75	5.79	.629	2.509
8	11.5	3.36	.220	2.260
8	13.75	4.02	.303	2.343
8	16.25	4.76	.395	2.435
8	18.75	5.49	.487	2.527
8	21.25	6.23	.579	2.619
9	13.4	3.89	.230	2.430
9	15.0	4.39	.285	2.485
9	20.0	5.86	.448	2.648
9	25.0	7.33	.612	2.812
10	15.3	4.47	.240	2.600
10	20.0	5.86	.379	2.739
10	25.0	7.33	.526	2.886
10	30.0	8.80	.673	3.033
10	35.0	10.27	.820	3.180
12	20.7	6.03	.280	2.940
12	25.0	7.32	.387	3.047
12	30.0	8.79	.510	3.170
12	35.0	10.26	.632	3.292
12	40.0	11.73	.755	3.415
15	33.9	9.90	.400	3.400
15	35.0	10.23	.422	3.422
15	40.0	11.70	.520	3.52
15	45.0	13.17	.618	3.618
15	50.0	14.64	.716	3.716
15	55.0	16.11	.814	3.814
18	42.7	12.48	.450	3.950
18	45.8	13.38	.500	4.000
18	51.9	15.18	.600	4.100
18	58.0	16.98	.700	4.200

Standard H-Beams

Depth of Beam Inches	Weight, per Foot Pounds	Area of Section Sq. Ins.	Thickness of Web Inch	Width of Flange Inches
4	13.8	3.99	.313	4.000
5	18.9	5.47	.313	5.000
6	20.0	5.86	.250	5.938
6	22.5	6.61	.375	6.063
6	25.0	7.33	.313	5.938
6	27.5	8.08	.438	6.063
8	32.6	9.50	.313	7.938
8	34.3	10.00	.375	8.000
8	37.7	11.00	.500	8.125

THEORETICAL WEIGHT OF STEEL PLATES

Size in Inches	Wt. per Square Ft. Lbs.	Size in Inches	Wt. per Square Ft. Lbs.	Size in Inches	Wt. per Square Ft. Lbs.	Size in Inches	Wt. per Square Ft. Lbs.
3/16	7.65	1	40.80	2½	102.00	5	204.00
¼	10.20	1⅛	45.90	2¾	112.20	5½	224.40
5/16	12.75	1¼	51.00	3	122.40	6	244.80
⅜	15.30	1⅜	56.10	3¼	132.60	6½	265.20
7/16	17.86	1½	61.20	3½	142.80	7	285.60
½	20.40	1⅝	66.30	3¾	153.00	7½	306.00
9/16	22.96	1¾	71.40	4	163.20	8	326.40
⅝	25.50	2	81.60	4¼	173.40	9	367.20
¾	30.60	2¼	91.80	4½	183.60	10	408.00
⅞	35.70						

BUILDING MATERIALS

Material	Average Ultimate Stress Pounds per Square Inch			Safe Working Stress Pounds per Square Inch			Modulus of Elasticity Pounds per Sq. In.
	Compression	Tension	Bending	Compression	Tension	Bending	
Masonry, granite	....	....	....	420	600		
" limestone, bluestone	....	....	....	350	500		
" sandstone	....	....	....	280	400		
" rubble	....	....	....	140	250		
" brick, common	10000	200	600				
Ropes, cast steel hoisting	....	80000					
" standing, derrick	....	70000					
" manila	....	8000					
Stone, bluestone	12000	1200	2500	1200	1200	200	7,000,000
" granite, gneiss	12000	1200	1600	1200	1200	200	7 000,000
" limestone, marble	8000	800	1500	800	800	150	7,000,000
" sandstone	5000	150	1200	500	500	150	3,000,000
" slate	10000	3000	5000	1000	1000	175	14,000,000

Galvanized Steel Sheets—Approx. Weight Per Sheet in Pounds

Size of Sheet in Inches	U. S. Standard Gauge										
	10	12	14	16	18	20	22	24	26	27	28	30
24x96	......	......	......	42.5	34.5	26.5	22.5	18.5	14.5	13.5	12.5	10.5
24x120	......	......	......	53.1	43.1	33.1	28.1	23.1	18.1	......	15.6	13.1
26x96	......	......	......	46.0	37.4	28.7	24.4	20.0	15.7	14.6	13.5	11.4
26x120	......	......	......	57.5	46.7	35.9	30.5	25.0	19.6	......	16.9	14.2
28x72	......	......	......	......	30.2	23.2	19.7	16.2	12.7	......	10.9	......
28x84	......	......	......	......	35.2	27.1	23.0	18.9	14.8	......	12.8	......
28x96	......	......	......	49.6	40.2	30.9	26.2	21.6	16.9	15.7	14.6	12.3
28x108	......	......	......	......	45.3	34.8	29.5	24.3	19.0	......	16.4	......
28x120	......	......	......	62.0	50.3	38.6	32.8	27.0	21.1	19.7	18.2	15.3
28x144	......	......	......	......	......	46.4	39.4	32.4	25.4	......	21.8	......
30x96	115.6	90.6	65.6	53.1	43.1	33.1	28.1	23.1	18.1	16.9	15.6	13.1
30x120	144.5	113.3	82.0	66.4	53.9	41.4	35.2	28.9	22.7	21.1	19.5	16.4
36x96	138.8	108.8	78.8	63.8	51.8	39.8	33.8	27.8	21.8	20.3	18.7	15.8
36x120	173.4	135.9	98.4	79.7	64.7	49.7	42.2	34.7	27.2	25.3	23.4	19.7
42x96	161.8	126.8	91.9	74.4	60.4	46.4	39.4	32.4	25.4	......	......	......
42x120	202.3	158.7	114.8	93.0	75.5	58.0	49.2	40.5	31.7	......	......	......
48x96	185.0	145.0	105.0	85.0	69.0	53.0	45.0	37.0	......	......	......	......
48x120	231.2	181.2	131.2	106.2	86.2	66.2	56.2	46.2	......	......	......	......

Maximum Electrical Carrying Capacity of Pure Copper Wire

American Gauge No.	Circular Millimeters	Current in Amperes	American Gauge No.	Circular Millimeters	Current in Amperes	American Gauge No.	Circular Millimeters	Current in Amperes
0000	211,600	450	7	20,816	75	17	2,048.2	15
000	167,805	375	8	16,509	67 5	18	1,624.3	12
00	133,079.4	315	9	13,094	60	19	1,252.4	9
0	105,592.5	270	10	10,381	45	20	1,021.5	7 5
1	83,694.2	225	11	8,234	37 5	21	810.1	6 75
2	66,373	180	12	6,525.9	30	22	642.7	6
3	52,634	150	13	5,178.4	27	23	509.45	5.25
4	41,742	120	14	4,106.8	24	24	404.01	4.5
5	33,102	105	15	3,256.7	21	25	320.4	3.75
6	26,250.5	90	16	2,582.9	18			

To Compute the Weight of Steel — Divide the thickness expressed in thousands by 25. The result is the weight in pounds per square foot. For weight of sheet brass add 11 per cent. For weight of sheet copper, add 10 per cent.

BOARD MEASURE—

One foot board measure is a piece of wood 12 inches square by 1 inch thick, or 144 cu. ins. 1 cu. ft. therefore, equals 12 feet board measure.

Weights of Steel Angles With Fillet

Per Lineal Foot in Pounds

Size, Inches	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/16	1 1/8
3/4x3/4	.59	.84	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1x1	.80	1.16	1.49	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1 1/4x1 1/4	1.01	1.48	1.92	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1 1/2x1 1/2	1.23	1.80	2.34	2.86	3.35	....	....	....	....	....	....	....	....	....	....	....	....
1 3/4x1 3/4	1.44	2.12	2.77	3.39	4.0	....	....	....	....	....	....	....	....	....	....	....	....
2x1 1/2	1.44	2.12	2.77	3.39	3.99	....	....	....	....	....	....	....	....	....	....	....	....
2x2	1.65	2.44	3.19	3.92	4.7	5.3	6.0	....	....	....	....	....	....	....	....	....	....
2 1/4x2 1/4	1.86	2.75	3.62	4.5	5.3	6.1	....	....	....	....	....	....	....	....	....	....	....
2 1/2x2	1.86	2.75	3.62	4.5	5.3	6.1	6.8	....	....	....	....	....	....	....	....	....	....
2 1/2x2 1/2	2.08	3.07	4.1	5.0	5.9	6.8	7.7	....	....	....	....	....	....	....	....	....	....
3x2	....	3.07	4.1	5.0	5.9	6.8	7.7	....	....	....	....	....	....	....	....	....	....
3x2 1/2	....	3.39	4.5	5.6	6.6	7.6	8.5	9.5	....	....	....	....	....	....	....	....	....
3 3	2.50	3.70	4.9	6.1	7.2	8.3	9.4	10.4	11.5	....	....	....	....	....	....	....	....
3 1/2x2 1/2	....	....	4.9	6.1	7.2	8.3	9.4	10.4	11.5	12.5	13.4	....	....	....	....	....	....
3 1/2x3	....	....	5.4	6.6	7.9	9.1	10.2	11.4	12.5	13.6	14.7	15.8	16.8	....	....	....	....
3 1/2x3 1/2	....	....	5.8	7.2	8.5	9.8	11.1	12.4	13.6	14.8	16.0	17.1	18.3	....	....	....	....
4x3	....	....	5.8	7.2	8.5	9.8	11.1	12.4	13.6	14.8	16.0	17.1	18.3	....	....	....	....
4x3 1/2	....	....	6.2	7.7	9.1	10.6	11.9	13.3	14.7	16.0	....	....	....	....	....	....	....
4x4	....	....	6.6	8.2	9.8	11.3	12.8	14.3	15.7	17.1	18.5	19.9	21.2	....	....	....	....
5x3	....	....	....	8.2	9.8	11.3	12.8	14.3	15.7	17.1	18.5	19.9	21.2	....	....	....	....
5x3 1/2	....	....	....	8.7	10.4	12.0	13.6	15.2	16.8	18.3	19.8	21.3	22.7	24.2	....	....	....
5x4	....	....	....	....	11.0	12.8	14.5	16.2	17.8	19.5	....	....	....	....	....	....	....
5x5	....	....	....	....	12.3	14.3	16.2	18.1	20.0	21.8	....	....	....	....	....	....	....
6x3 1/2	....	....	....	9.8	11.7	13.5	15.3	17.1	18.9	20.6	22.4	24.0	25.7	27.3	28.9	....	....
6x4	....	....	....	10.3	12.3	14.3	16.2	18.1	20.0	21.8	23.6	25.4	27.2	28.9	30.6	....	....
6x6	....	....	....	....	14.9	17.2	19.6	21.9	24.2	26.5	28.7	31.0	33.1	35.3	37.4	....	....
7x4	....	....	....	....	13.6	15.8	17.9	20.0	22.1	24.2	26.2	28.2	30.2	32.1	34.0	....	....
8x4	....	....	....	....	....	17.2	19.6	21.9	24.2	26.5	28.7	31.0	33.1	35.3	37.4	....	....
8x6	....	....	....	....	....	20.2	23.0	25.7	28.5	31.2	33.8	36.5	39.1	41.7	44.2	....	....
8x8	....	....	....	....	....	....	26.4	29.6	32.7	35.8	38.9	42.0	45.0	48.1	51.0	54.0	56.9

STANDARD WROUGHT WASHERS

Packed in 200-Pound Kegs

Outside Diameter	Size of Hole	Thickness Wire Gauge		Size of Bolt	Number Per 100 Pounds	Weight Per 1000 Pieces
		Number	Inches			Pounds
9/16	1/4	18	3/64	3/16	27,800	3.6
3/4	5/16	16	1/16	1/4	15,600	6.4
7/8	3/8	16	1/16	5/16	11,250	8.8
1	7/16	14	5/64	3/8	6,800	14.7
1 1/4	1/2	14	5/64	7/16	4,300	23.
1 3/8	9/16	12	3/32	1/2	2,600	38.4
1 1/2	5/8	12	3/32	9/16	2,250	44.4
1 3/4	11/16	10	1/8	5/8	1,300	77.
2	13/16	9	5/32	3/4	900	111.
2 1/4	15/16	8	11/64	7/8	782	130.
2 1/2	1 1/16	8	11/64	1	568	176.
2 3/4	1 1/4	8	11/64	1 1/8	473	211.
3	1 3/8	8	11/64	1 1/4	364	272.
3 1/4	1 1/2	7	3/16	1 3/8	275	364.
3 1/2	1 5/8	7	3/16	1 1/2	256	390.
3 3/4	1 3/4	7	3/16	1 5/8	220	454.
4	1 7/8	7	3/16	1 3/4	197	508.
4 1/4	2	7	3/16	1 7/8	174	575.
4 1/2	2 1/8	7	3/16	2	160	625.
4 3/4	2 3/8	5	7/32	2 1/4	122	820.
5	2 5/8	4	15/64	2 1/2	106	943

Weights of Materials

The weights given represent averages for standards of various states, as given in circulars issued by the United States Government, and are also compiled from those given by Cambria.

They represent, in many cases, the weights of materials as settled or packed in bins, while lower weights should generally be figured for materials as slightly agitated or fluffed by handling in elevators, screw conveyors, etc.

Material	Average Weight of One Cu. Ft., Pounds	Specific Gravity Water = 1.
Alcohol, proof spirit	58	.79
Aluminum, cast, pure	160	2.55
Anthracite, broken, loose	55	1.5
Asbestos	175	2.8
Ash, American White, dry (wood)	47	.75
Ashes of soft coal, solidly packed	40	....
Asphaltum	87	1.4
Barley	38	....
Barytes	180	....
Batch, Glass	90	....
Beans	48	....
Benzine	50	.85
Bauxite, Crushed	80	....
Bran	16	....
Brass (copper and zinc), cast	519	8.20 to 8.60
Brick, best pressed	134	2.15
Brick, common and hard	112–125	....
Brick, fire	144	....
Brickwork, cement	112	....
Bronze, copper 8, tin 1 (gun metal)	552	8.85
Cedar	24	.57
Cement, Portland, per barrel, net, 376 pounds	100	1.6
Cement, Portland, standard proportioning	100	1.6
Chalk	156	2.5
Char	45	....
Charcoal of pines and oaks	20 to 38	....
Cherry, perfectly dry	44	.70
Chestnut wood, dry	38	.60
Cinder, blast furnace	57	....
Cinders (coal, ashes and clinkers)	40	.64
Clay, dry, in lump, loose	75	....
Clinker, cement	80 to 95	....
Coal, bituminous, solid	84	1.27
Coal, Bituminous, broken, of any size, piled	44 to 52	....
Coal, Steam	50	....
Coke, Breeze	25–34	....
Coke, Refiners'	35–40	....
Coke, loose, good quality	23 to 32	....
Concrete, conglomerate, with Portland cement	143–150	....
Concrete, gravel, with Portland cement	150	2.4
Concrete, loose, unrammed, weighs 5 to 25% lighter, varying with consistency.		
Copper, cast	542	8.7
Copper, rolled	555	8.9
Corn, Shelled	45	.64
Corn, meal	40	.64
Cork, dry	15	.24
Cotton seed	25	....
Cotton seed cake, cracked	41	....
Cotton seed hulls	12	....
Cotton seed meal	35	....
Cullet	80 to 120	....
Cypress	38	.60
Earth, common loam, perfectly dry, loose	72 to 80	1.2
Earth, common loam, perfectly dry, shaken	82 to 92	1.2
Elm, perfectly dry	42	.67
Feldspar, powdered	75	....
Fir	35	.55
Flax seed	45	....
Flour, 196 pounds per barrel, net	35 to 40	....
Fullers earth	35 to 45	....
Glass	163	2.6

Material	Average Weight of One Cu. Ft., Pounds	Specific Gravity Water = 1.
Gold, pure cast, 24K	1206	19.32
Granite, solid	166	2.65
Granite, broken	96	....
Gravel	100	1.75
Gypsum, under 1" Crushed	80 to 100	....
Gypsum, powered	60 to 80	2.2
Hay, baled	24	....
Hemlock, perfectly dry	25	.40
Hides green, 85 pounds each	....	....
Hickory, perfectly dry	50	.80
Ice,	56	.90
Iron, cast	446	7.15
Iron, wrought	480	7.69
Lead, commercial	709.6	11.38
Lignumvitae (dry)	41 to 83	.66 to 1.3
Limestone, loose	96	2.6
Lime, quick	95	1.5
Lime, quick, ground, well shaken	64	....
Lime, hydrated	20 to 45	....
Locust, dry	46	.73
Magnesium	109	1.75
Mahogany	56	.90
Manganese	500	....
Maple, dry	44	.70
Marble, crushed	90	2.6
Marl	79	....
Oak, live, perfectly dry, .88 to 1.02	72	1.15
Oak, white, perfectly dry	50	.80
Oats	26	....
Oil, linseed	59	.94
Oil, petroleum	51	.82
Oil, olive and whale	58	.92
Ore, zinc, crushed	160	....
Ore, soft iron	150	....
Oxide, Iron Sponge	28 to 50	....
Phosphate acid	62	....
Phosphate Pebble	100	....
Phosphate rock	85	....
Pine, white, perfectly dry	32	.50
Pine, Yellow Southern, perfectly dry	41	.65
Poplar, dry	32	.50
Quartz	90 to 100	....
Salt, coarse	45	....
Salt, dry, fines	80	....
Sand, damp	117 to 130	....
Sand, dry	90 to 110	....
Sandstone, quarried and piled	86	....
Sawdust	13	....
Shales	92	....
Slag	160 to 180	....
Slag, furnace, granulated	53	....
Slate	175	2.8
Slurry, cement	90	....
Soda	42	....
Soda ash	32 to 67	....
Spruce, dry	25	.40
Steel	486.5	7.80
Straw, baled	24	....
Sugar, refined	55	....
Sulphur	125	2.0
Tar	62.4	1.0
Tin, cast, 7.2	455	7.29
Trap rock, crushed	97 to 107	3.0
Turpentine, 300 pounds per barrel	....	.87
Walnut, Black, perfectly dry (see note below)	41	.65
Water, pure rain, distilled, at 32 degrees F., Bar. 30 inches	62.417	1.00
Water, sea	64.08	1.03
Wheat	48	....
Zinc or Spelter, cast	428	6.86

Cotton Bales, Weight 500 lbs. Full Bale, not compressed, size, 27"x54"x42".

Full Bale, compressed, size, 27"x54"x18".

The sizes of cotton bales vary according to the baling machine used, and amount of compression A fair average is given above.

TIMBER

AMERICAN STANDARD SIZES

PROPERTIES FOR DESIGNING

NATIONAL LUMBER MANUFACTURERS ASSOCIATION

Nominal Size	American Standard Dressed Size	Area of Section	Weight per Foot	Moment of Inertia	Section Modulus
In.	In.	In.²	Lb.	In.⁴	In.³
2 x 4	1⅝x3⅝	5.89	1.64	6.45	3.56
6	5⅝	9.14	2.54	24.1	8.57
8	7½	12.2	3.39	57.1	15.3
10	9½	15.4	4.29	116	24.4
12	11½	18.7	5.19	206	35.8
14	13½	21.9	6.09	333	49.4
16	15½	25.2	6.99	504	65.1
18	17½	28.4	7.90	726	82.9
3 x 4	2⅝x3⅝	9.52	2.64	10.4	5.75
6	5⅝	14.8	4.10	38.9	13.8
8	7½	19.7	5.47	92.3	24.6
10	9½	24.9	6.93	188	39.5
12	11½	30.2	8.39	333	57.9
14	13½	35.4	9.84	538	79.7
16	15½	40.7	11.3	815	105
18	17½	45.9	12.8	1172	134
4 x 4	3⅝x3⅝	13.1	3.65	14.4	7.94
6	5⅝	20.4	5.66	53.8	19.1
8	7½	27.2	7.55	127	34.0
10	9½	34.4	9.57	259	54.5
12	11½	41.7	11.6	459	79.9
14	13½	48.9	13.6	743	110
16	15½	56.2	15.6	1125	145
18	17½	63.4	17.6	1619	185
6 x 6	5½x5½	30.3	8.40	76.3	27.7
8	7½	41.3	11.4	193	51.6
10	9½	52.3	14.5	330	82.7
12	11½	63.3	17.5	697	121
14	13½	74.3	20.6	1128	167
16	15½	85.3	23.6	1707	220
18	17½	96.3	26.7	2456	281
20	19½	107.3	29.8	3398	349
8 x 8	7½x7½	56.3	15.6	264	70.3
10	9½	71.3	19.8	536	113
12	11½	86.3	23.9	951	165
14	13½	101.3	28.0	1538	228
16	15½	116.3	32.0	2327	300
18	17½	131.3	36.4	3350	383
20	19½	146.3	40.6	4634	475
22	21½	161.3	44.8	6211	578

Nominal Size	American Standard Dressed Size	Area of Section	Weight per Foot	Moment of Inertia	Section Modulus
In.	In.	In.²	Lb.	In.⁴	In.³
10x10	9½x 9½	90.3	25.0	679	143
12	11½	109	30.3	1204	209
14	13½	128	35.6	1948	289
16	15½	147	40.9	2948	380
18	17½	166	46.1	4243	485
20	19½	185	51.4	5870	602
22	21½	204	56.7	7868	732
24	23½	223	62.0	10274	874
12x12	11½x11½	132	36.7	1458	253
14	13½	155	43.1	2358	349
16	15½	178	49.5	3569	460
18	17½	201	55.9	5136	587
20	19½	224	62.3	7106	729
22	21½	247	68.7	9524	886
24	23½	270	75.0	12437	1058
14x14	13½x13½	182	50.6	2768	410
16	15½	209	58.1	4189	541
18	17½	236	65.6	6029	689
20	19½	263	73.1	8342	856
22	21½	290	80.6	11181	1040
24	23½	317	88.1	14600	1243
16x16	15½x15½	240	66.7	4810	621
18	17½	271	75.3	6923	791
20	19½	302	83.9	9578	982
22	21½	333	92.5	12837	1194
24	23½	364	101	16763	1427
18x18	17½x17½	306	85.0	7816	893
20	19½	341	94.8	10813	1109
22	21½	376	105	14493	1348
24	23½	411	114	18926	1611
26	25½	446	124	24181	1897
20x20	19½x19½	380	106	12049	1236
22	21½	419	116	16150	1502
24	23½	458	127	21089	1795
26	25½	497	138	26945	2113
28	27½	536	149	33795	2458
24x24	23½x23½	552	153	25415	2163
26	25½	599	166	32472	2547
28	27½	646	180	40727	2962
30	29½	693	193	50275	3408

All properties and weights given are for dressed size only.
The weights given above are based on assumed average weight of 40 pounds per cubic foot.

STRUCTURAL TIMBER COLUMNS

ALLOWABLE UNIT STRESSES

POUNDS PER SQUARE INCH

FOREST PRODUCTS LABORATORY, DEPARTMENT OF AGRICULTURE

Species of Timber	American Standard Grade	Ratio of Length to Least Dimension (l/d)										
		10 and Less	12	14	16	18	20	25	30	35	40	50
Ash, Commercial White	Select	1100	1076	1055	1023	978	913	658	457	336	257	164
	Common	880	868	857	840	818	784	647				
Cedar, Western Red; Fir, Balsam	Select	700	686	674	656	629	592	438	304	224	171	110
	Common	560	553	547	538	524	505	425				
Cedar, Northern and Southern White	Select	550	540	530	516	496	468	351	244	179	137	88
	Common	440	435	430	423	412	398	338				
Chestnut; Pine, Northern White, Idaho White, Sugar, Calif. White, and Pondosa	Select	750	733	718	695	663	617	438	304	224	171	110
	Common	600	591	583	572	556	532	434				
Cypress, Southern; Larch, Western	Select	1100	1063	1030	981	909	810	526	365	268	206	132
	Common	880	861	843	818	781	729					
Douglas Fir (Coast Region); Pine, Southern Yellow; Beech; Birch, Yellow and Sweet; Maple, Sugar	Dense Select	1285	1251	1222	1176	1112	1022	702				
	Select	1175	1149	1127	1093	1045	975	702	487	358	274	175
	Common	880	870	861	847	826	796	675				
Douglas Fir (Rocky Mtn. Region); Spruce, Red, White, Sitka; Norway Pine; Alaska Cedar; Elm, Slippery and White; Sycamore; Gum, Red and Black; Tupelo	Select	800	786	774	753	726	688	526	365	268	206	132
	Common	640	632	627	617	602	582	500				
Hemlock, West Coast	Select	900	885	872	852	823	783	614	426	313	240	153
	Common	720	712	706	696	680	660	573				
Hemlock, Eastern; Fir, Commercial White	Select	700	689	678	664	641	611	482	335	246	188	121
	Common	560	554	549	542	530	515	449				
Oak, White and Red	Select	1000	982	967	943	908	860	658	457	336	257	164
	Common	800	790	783	771	753	728	625				
Redwood	Select	1000	972	947	910	856	781	526	365	268	206	132
	Common	800	786	773	754	726	688					
Spruce, Englemann	Select	600	586	574	556	530	494	351	244	179	137	88
	Common	480	473	466	457	444	426	347				
Tamarack	Select	1000	976	955	923	877	817	570	396	291	223	142
	Common	800	788	777	761	737	706	566				

No column shall be used in which the unsupported length is more than 50 times the least diameter. l and d must be figured in the same unit of measurement.

The strength of wood is influenced considerably by its moisture content. For wet locations the allowable working stresses should be reduced according to conditions and timber used. Recommendations covering specific cases may be obtained from the Forest Products Laboratory.

SPECIFIC GRAVITY AND WEIGHT OF SOLID SUBSTANCES, EXCEPT METALS AND WOOD

Substance	Specific Gravity	Average Weight, Lb. per Cu. Ft.	Substance	Specific Gravity	Average Weight, Lb. per Cu. Ft.
Asbestos	2.1–2.8	153	Hornblende	3.2–3.52	210
Ashes	....	43	Ice	0.88–0.92	55–57
Asphaltum	1.39	87	Leather	0.86–1.02	59
Barytes	4.50	281	Lime, quick, in bulk	0.8–0.96	55
Basalt	2.7–3.2	184	Limestone	2.3–2.9	160
Bauxite	2.55	159	Magnesia, carbonate	2.4	150
Bluestone	2.2–2.5	147	Magnesite	3.0	187
Brick, soft	1.6	100	Marble	2.56–2.88	170
Brick, common	1.79	112	Masonry, dry, rubble	2.24–2.56	150
Brick, hard	2.0	125	Masonry, dressed	2.24–2.88	160
Brick, pressed	2.16	135	Mica	2.80	175
Brick, fire	2.24–2.4	145	Mortar	1.44–1.6	95
Brick, sand-lime	2.18	136	Mud	1.7–1.8	111
Brickwork, mortar	1.6	100	Paper	0.70–1.15	58
Brickwork, cement	1.79	112	Paraffin	0.87–0.91	56
Borax	1.7–1.8	112	Peat	0.65–0.85	47
Cement, American, natural	2.8–3.2	187	Phosphate rock	3.2	200
Cement, Portland	3.05–3.15	190	Pitch	1.15	72
Cement, Portland loose	1.44	92	Plaster-of-Paris	1.5–1.8	103
Cement, Portland barreled	1.84	115	Porcelain	2.3–2.5	250
Cement, slag	1.9–2.3	130	Porphyry	2.6–2.9	172
Chalk	1.8–2.6	137	Pumice	0.37–0.90	40
Clay	1.92–2.4	137	Riprap, limestone	1.3–1.4	80–85
Coal, anthracite	1.4–1.8	97	Riprap, sandstone	1.4	90
Coal, bituminous	1.2–1.5	84	Riprap, shale	1.7	105
Coal, lignite	1.1–1.4	78	Rubber, caoutchouc	0.92–0.96	59
Coal, charcoal	0.27–0.58	18	Rubber, manufactured	1.0–2.0	95
Coke	1.0–1.4	22–27	Salt	0.77	48
Concrete	1.92–2.48	133	Saltpeter	1.07	67
Cork	0.22–0.26	15	Sand	1.44–1.76	100
Dolomite	2.9	181	Sand wet	1.89–2.07	125
Earth, dry, loose	1.2	75	Sandstone	2.24–2.4	145
Earth, dry, packed	1.5	93	Serpentine	2.4–2.7	165
Earth, moist, loose	1.3	81	Shale	2.6–2.9	172
Earth, moist, packed	1.6	100	Slag, bank	1.1–1.2	69
Earth, mud, flowing	1.7	106	Slag, bank screenings	1.5–1.9	107
Earth, mud, packed	1.8	112	Slag, machine	1.5	96
Emery	4.0	250	Slag, sand	0.8–0.9	53
Feldspar	2.5–2.6	159	Slate	2.72–2.88	175
Glass, common	2.5–2.75	164	Soapstone	2.65–2.8	170
Glass, crystal	2.90–3.00	184	Starch	1.53	96
Glass, flint	2.9–2.31	188	Stone, various	2.16–3.4	135–200
Glass, plate	2.45–2.72	161	Stone, crushed	1.6	100
Gneiss	2.4–2.7	165	Sulphur	1.93–2.07	125
Granite	2.5–3.1	179	Talc	2.6–2.8	169
Graphite	1.9–2.3	126	Tar, bituminous	1.20	75
Gravel, dry, loose	1.4–1.7	90–105	Terra-cotta	1.9	119
Gravel, dry, packed	1.6–1.9	100–120	Tile	1.76–1.92	115
Gravel, wet	1.9	120	Trap rock	2.72–3.4	185
Greenstone	2.8–3.2	187	Wool	1.32	82
Gypsum	2.08–2.4	140			

MELTING POINT OF SUBSTANCES

Substance.	Melts °F.	Substance.	Melts °F	Substance.	Melts °F.
Asphaltum	210	Nitroglycerine	45	Spermaceti	120
Bees-wax	154	Parafine	130	Stearine	128
Ice	32	Phosphorous	112	Sulphur	239
Iodine	225	Rosin	175	Water freezes	32
Mercury	39	Selenium	442	Tallow	92

WEIGHTS AND SPECIFIC GRAVITY OF METALS

Metals, Etc.	Weight, per Cubic in. lb.	Weight, per Cubic Ft. Lbs.	Specific Gravity	Melting Point Deg. F.
Aluminum	0.0924	159.7	2.67	1218
Antimony	0.2422	418.7	6.71	1166
Barium	0.1354	234.0	3.75	1562
Bismuth	0.3538	611.5	9.80	520
Boron	0.0939	162.2	2.60	4000-4500
Brass	0.3032	524.1	8.40	1700-1850
Bronze	0.3195	552.2	8.85	1675
Cadmium	0.3105	536.6	8.60	610
Calcium	0.0567	98.0	1.57	1490
Chromium	0.2347	405.6	6.50	2939
Cobalt	0.3123	539.8	8.65	2696
Copper	0.3184	550.4	8.82	1981
Gold	0.6975	1205.6	19.32	1945
Iridium	0.8094	1399.0	22.42	4260
Iron Cast	0.2600	449.2	7.20	2300
Iron Wrought	0.2834	489.8	7.85	2750
Lead	0.4105	709.5	11.37	620
Magnesium	0.0628	108.6	1.74	1204
Manganese	0.2679	463.0	7.42	2246
Mercury	0.4902	847.4	13.58	−38
Molybdenum	0.3090	534.2	8.56	4620
Nickel	0.3177	549.1	8.80	2646
Platinum Rolled	0.8184	1414.6	22.67	3191
Platinum Wire	0.7595	1312.9	21.04	3191
Potassium	0.0314	54.3	0.87	144
Silver	0.3802	657.1	10.53	1761
Sodium	0.0354	61.1	0.98	207
Steel	0.2816	486.7	7.80	2500
Tellurium	0.2256	390.0	6.25	846
Tin	0.2632	454.8	7.29	449
Titanium	0.1278	220.9	3.54	3272
Tungsten	0.6776	1171.2	18.77	6152
Vanadium	0.1986	343.2	5.50	3128
Zinc Cast	0.2476	428.1	6.86	787
Zinc Rolled	0.2581	446.1	715	787

SPECIFIC GRAVITY OF LIQUIDS

Liquid	Spacific Gravity	Liquid	Spacific Gravity	Liquid	Spacific Gravity
Acetic acid	1.06	Fluoric acid	1.50	Petroleum oil	0.82
Alcohol, commercial	0.83	Gasoline	0.70	Phosphoric acid	1.78
Alcohol, pure	0.79	Kerosene	0.80	Rape oil	0.92
Ammonia	0.89	Linseed oil	0.94	Sulphuric acid	1.84
Benzine	0.69	Mineral oil	0.92	Tar	1.00
Bromine	2.97	Muriatic acid	1.20	Turpentine oil	0.87
Carbolic acid	0.96	Naphtha	0.76	Vinegar	1.08
Carbon disulphide	1.26	Nitric acid	1.22	Water	1.00
Cotton-seed oil	0.93	Olive oil	0.92	Water, sea	1.03
Ether, sulphuric	0.72	Palm oil	0.97	Wale oil	0.92

MELTING POINTS OF COMMON METALS

Metal	° Fahr.	Metal	° Fahr.	Metal	° Fahr.
Mercury	—38	Gold	1945	Platinum	3191
Sulphur (SI)	236	Copper	1981	Molybdenum	4595
Tin	450	Manganese	2300	Tantalum	5252
Bismuth	520	Silicon	2588	Tungsten	6152
Cadmium	610	Nickel	2646	Carbon	6332
Lead	621	Cobalt	2696	Brass	1700-1850
Zinc	787	Chromium	2768	Bronze	1675
Antimony	1166	Iron	2786	Solder (50-50)	450
Magnesium	1204	Palladium	2820	Babbitt Metals	350-450
Aluminum	1218	Zirconium	3090	Zinc Die Casting Alloy	715-720
Silver	1761	Vanadium	3128		

Different Standards for Wire Gauge

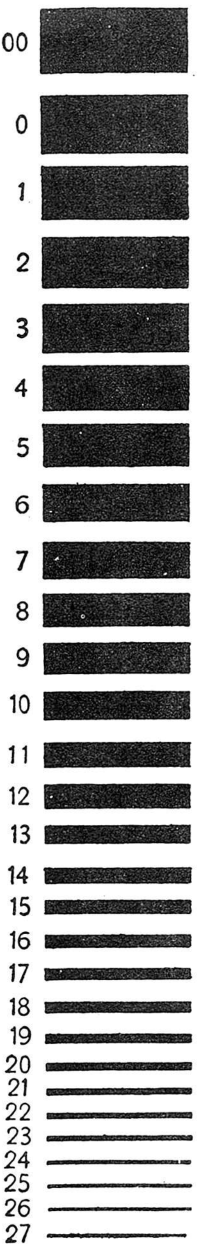
IN USE IN THE UNITED STATES

Dimensions of Sizes in Decimal Parts of an Inch

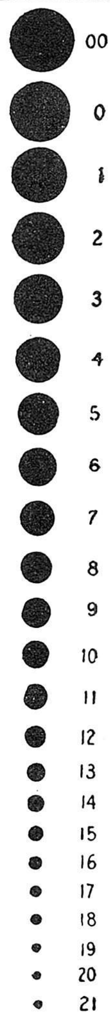
No. of Wire Gauge	Brown & Sharpe	Birmingham, or Stubs' Iron Wire	Washburn & Moen	Stubs' Steel Wire	U. S. Standard for Plate	Music Wire (A. S. & W. Co.)	Zinc Gauge
000000	.58000	....	.4615	....	.46875	.004	....
00000	.51650	.500	.4305	....	.4375	.005	....
0000	.46000	.454	.3938	....	.40625	.006	....
000	.40964	.425	.3625	....	.375	.007	....
00	.36480	.38	.3310	....	.34375	.008	....
0	.32486	.34	.3065	....	.3125	.009	....
1	.28930	.3	.2830	.227	.28125	.010	....
2	.25763	.284	.2625	.219	.265625	.011	....
3	.22942	.259	.2437	.212	.25	.012	.006
4	.20431	.238	.2253	.207	.234375	.013	.008
5	.18194	.22	.2070	.204	.21875	.014	.010
6	.16202	.203	.1920	.201	.203125	.016	.012
7	.14428	.18	.1770	.199	.1875	.018	.014
8	.12849	.165	.1620	.197	.171875	.020	.016
9	.11443	.148	.1483	.194	.15625	.022	.018
10	.10189	.134	.1350	.191	.140625	.024	.020
11	.090742	.12	.1205	.188	.125	.026	.024
12	.080808	.109	.1055	.185	.109375	.029	.028
13	.071961	.095	.0915	.182	.09375	.031	.032
14	.064084	.083	.0800	.180	.078125	.033	.036
15	.057068	.072	.0720	.178	.0703125	.035	.040
16	.050820	.065	.0625	.175	.0625	.037	.045
17	.045257	.058	.0540	.172	.05625	.039	.050
18	.040303	.049	.0475	.168	.05	.041	.055
19	.035890	.042	.0410	.164	.04375	.043	.060
20	.031961	.035	.0348	.161	.0375	.045	.070
21	.028462	.032	.03175	.157	.034375	.047	.080
22	.025347	.028	.0286	.155	.03125	.049	.090
23	.022571	.025	.0258	.153	.028125	.051	.100
24	.020100	.022	.0230	.151	.025	.055	.125
25	.017900	.02	.0204	.148	.021875	.059	....
26	.015940	.018	.0181	.146	.01875	.063	....
27	.014195	.016	.0173	.143	.0171875	.067	....
28	.012641	.014	.0162	.139	.015625	.071	....
29	.011257	.013	.0150	.134	.0140625	.075	....
30	.010025	.012	.0140	.127	.0125	.080	....
31	.008928	.01	.0132	.120	.0109375	.085	....
32	.007950	.009	.0128	.115	.01015625	.090	....
33	.007080	.008	.0118	.112	.009375	.095	....
34	.006304	.007	.0104	.110	.00859375	.098	....
35	.005614	.005	.0095	.108	.0078125	....	....
36	.005000	.004	.0090	.106	.00703125	....	....
37	.004453	....	.0085	.103	.006640625	....	....
38	.003965	....	.0080	.101	.00625	....	....
39	.003531	....	.0075	.099	....	....	....
40	.003144	....	.0070	.097	....	....	....

To Copper the Surface of Iron and Steel Wire— Have the wire perfectly clean, then wash with the following solution, when it will present at once, a coppered face: Rain water, three pounds; sulphate of copper, one pound.

Standard Gauges—Sheets, Plates and Wire



Number of Gauge	Thickness and Weight of Sheets and Plates								Thickness of Wire
	U.S. Standard Gauge Adopted by U. S. Government July 1, 1893			Birmingham or Stubs' Gauge		American or Brown & Sharpe's Gauge		Washburn & Moen Gauge
	Thickness, Inches		Weight, Pounds, per Sq. Ft.	Thickness, Inches	Weight, Pounds, per Sq. Ft.	Thickness, Inches	Weight, Pounds, per Sq. Ft.	Thickness, Inches
0000000	$\frac{1}{2}$	.5000	20.4	.....	.....	.....	.....	.....
000000	$\frac{15}{32}$	.46875	19.125	.....	.....	.580	23.6	.....
00000	$\frac{7}{16}$	.4375	17.85	.....	.....	.5165	21.0	.....
0000	$\frac{13}{32}$	.40625	16.575	.454	18.5	.46	18.71	.3938
000	$\frac{3}{8}$	.375	15.30	.425	17.28	.409	16.71	.....
00	$\frac{11}{32}$	.343	14.025	.38	15.45	.364	14.88	.331
0	$\frac{5}{16}$	.312	12.75	.34	13.82	.324	13.26	.307
1	$\frac{9}{32}$	.281	11.475	.30	12.20	.289	11.80	.283
2	$\frac{17}{64}$	.265	10.837	.284	11.55	.257	10.51	.263
3	$\frac{1}{4}$	.25	10.2	.259	10.53	.229	9.36	.244
4	$\frac{15}{64}$	.234	9.562	.238	9.68	.204	8.34	.225
5	$\frac{7}{32}$	.218	8.925	.22	8.95	.181	7.42	.207
6	$\frac{13}{64}$	.203	8.287	.203	8.25	.162	6.61	.192
7	$\frac{3}{16}$	.187	7.65	.18	7.32	.144	5.89	.177
8	$\frac{11}{64}$	.171	7.012	.165	6.71	.128	5.24	.162
9	$\frac{5}{32}$	.156	6.375	.148	6.02	.114	4.67	.148
10	$\frac{9}{64}$	.140	5.737	.134	5.45	.101	4.16	.135
11	$\frac{1}{8}$	.125	5.1	.12	4.88	.09	3.70	.120
12	$\frac{7}{64}$	.109	4.462	.109	4.43	.08	3.30	.105
13	$\frac{3}{32}$	.093	3.825	.095	3.86	.072	2.94	.092
14	$\frac{5}{64}$	.078	3.187	.083	3.37	.064	2.62	.080
15	$\frac{9}{128}$	.070	2.868	.072	2.93	.057	2.33	.072
16	$\frac{1}{16}$	.062	2.55	.065	2.64	.05	2.07	.063
17	$\frac{9}{160}$	.056	2.295	.058	2.36	.045	1.85	.054
18	$\frac{1}{20}$	.05	2.04	.049	1.99	.04	1.64	.047
19	$\frac{7}{160}$	.043	1.785	.042	1.71	.035	1.46	.041
20	$\frac{3}{80}$	.037	1.53	.035	1.42	.032	1.31	.035
21	$\frac{11}{320}$	.034	1.402	.032	1.30	.028	1.16	.032
22	$\frac{1}{32}$	.031	1.275	.028	1.14	.025	1.03	.....
23	$\frac{9}{320}$	.028	1.147	.025	1.02	.022	.922	.....
24	$\frac{1}{40}$	.025	1.02	.022	.895	.020	.82	.....
25	$\frac{7}{320}$	.021	.892	.02	.813	.017	.73	.....
26	$\frac{3}{160}$	.018	.765	.018	.732	.015	.649	.....
27	$\frac{11}{640}$	.017	.701	.016	.651	.014	.579	.....
28	$\frac{1}{64}$	.015	.637	.014	.569	.012	.514	.....
29	$\frac{9}{640}$	.014	.573	.013	.....	.011	.461	.....
30	$\frac{1}{80}$	.012	.51	.012	.....	.01	.408	.....



Sheet mills roll steel sheets to U. S. gauge unless otherwise ordered. Plate mills usually roll heavy plates, $\frac{3}{16}$ and heavier, and light plate No. 8 to No. 12, to Birmingham gauge. In figuring weights of steel plates add to above the allowance for overweight, adopted by Association American Steel Manufacturers.

SAFE LOADS FOR ROPES AND CHAINS
(In Pounds)

CAUTION: When handling molten metal, Wire Rope and chains should be 25% Stronger than indicated in table.

NOTE: Safe loads in table are for each single rope and chain Used double or in multiples, increase loads in proportion		*Breaking Stress*	SAFE LOADS *When Used Straight*	*When Used at* 60 *Multiply by 0.866*	*When Used at* 45 *Multiply by 0.70711*	*When Used at* 30 *Multiply by 9.500*
	DIA.					
PLOW STEEL WIRE ROPE	3/8	10,200	2,000	1,730	1,400	1,000
	1/2	19,500	3,700	3,200	2,600	1,800
	5/8	28,000	6,000	5,200	4,200	3,000
6 Strands of 19 or 31 Wires	3/4	42,000	8,000	7,000	5,650	4,000
	7/8	54,000	10,000	8,700	7,070	5,000
If Crusible Steel Rope is used Reduce Loads 20 %	1	70,000	14,000	12,000	10,000	7,000
	1 1/8	88,000	18,000	15,600	12,700	9,000
	1 1/4	110,000	22,000	19,000	15,600	11,000
	1 3/8	136,000	28,000	24,200	20,000	14,000
	1 1/2	160,000	32,000	27,500	22,600	16,000
	DIA OF IRON					
CRANE CHAIN	1/4	5000	1,000	860	700	500
	3/8	10000	2,000	1,730	1,400	1000
Best made of wrought Iron hand made tested short link chain	1/2	18000	3,600	3100	2,550	1,800
	5/8	27000	5400	4600	3800	2700
	3/4	40,000	8000	8,900	5,650	4,000
	7/8	48,000	9,600	8,300	6,800	4800
	1	61,000	12,200	10,700	8,800	6,100
	1 1/8	78,000	15,600	13,500	11,000	7800
	1 1/4	95,000	19,000	16,400	13,400	9,500
	1 3/8	114,000	23,000	20,000	16,100	11,500

Comparative Weights of Steel and Brass Bars

Steel—Weights cover hot worked steel about 50% carbon. One cubic inch weighs .2833 lbs. High speed steel 10% heavier.

Brass—One cubic inch weighs .3074 lbs.

Actual weight of stock may be expected to vary somewhat from these figures because of variations in manufacturing processes.

Size, Inches	Weight of Bar One Foot Long, Lbs.					
	Steel			Brass		
	○	□	⬡	○	□	⬡
1/16	.0104	.013	.0115	.0113	.0144	.0125
1/8	.042	.05	.046	.045	.058	.050
3/16	.09	.12	.10	.102	.130	.112
1/4	.17	.21	.19	.18	.23	.20
5/16	.26	.33	.29	.28	.36	.31
3/8	.38	.48	.42	.41	.52	.45
7/16	.51	.65	.56	.55	.71	.61
1/2	.67	.85	.74	.72	.92	.80
9/16	.85	1.08	.94	.92	1.17	1.01
5/8	1.04	1.33	1.15	1.13	1.44	1.25
11/16	1.27	1.61	1.40	1.37	1.74	1.51
3/4	1.50	1.92	1.66	1.63	2.07	1.80
13/16	1.76	2.24	1.94	1.91	2.43	2.11
7/8	2.04	2.60	2.25	2.22	2.82	2.45
15/16	2.35	2.99	2.59	2.55	3.24	2.81
1	2.67	3.40	2.94	2.90	3.69	3.19
1 1/16	3.01	3.84	3.32	3.27	4.16	3.61
1 1/8	3.38	4.30	3.73	3.67	4.67	4.04
1 3/16	3.77	4.80	4.16	4.08	5.20	4.51
1 1/4	4.17	5.31	4.60	4.53	5.76	4.99
1 5/16	4.60	5.86	5.07	4.99	6.35	5.50
1 3/8	5.04	6.43	5.56	5.48	6.97	6.04
1 7/16	5.52	7.03	6.08	5.99	7.62	6.60
1 1/2	6.01	7.65	6.63	6.52	8.30	7.19
1 9/16	6.52	8.30	7.19	7.07	9.01	7.80
1 5/8	7.05	8.98	7.77	7.65	9.74	8.44
1 11/16	7.60	9.68	8.38	8.25	10.51	9.10
1 3/4	8.18	10.41	9.02	8.87	11.30	9.78
1 13/16	8.77	11.17	9.67	9.52	12.12	10.49
1 7/8	9.39	11.95	10.35	10.19	12.97	11.24
1 15/16	10.02	12.76	11.05	10.88	13.85	12.00
2	10.68	13.60	11.78	11.59	14.76	12.78
2 1/16	11.36	14.46	12.53	12.33	15.69	13.60
2 1/8	12.06	15.35	13.30	13.08	16.66	14.42
2 3/16	12.78	16.27	14.09	13.87	17.65	15.29
2 1/4	13.52	17.22	14.91	14.67	18.68	16.17
2 5/16	14.28	18.19	15.75	15.50	19.73	17.09
2 3/8	15.06	19.18	16.62	16.34	20.81	18.02

For weight of Hexagon and Octagon Rods, take weight of Round and Square, add together, and divide by two.
Specify Gravity = 8.509. Weight per Cubic Inch = .3074 lbs. Weight per Cubic Foot = 531.1 lbs.
These weights are theoretically correct but variations must be expected in practice

CASE HARDENING CAST IRON.—Salt, 21 lbs.; saltpetre, 1/2 lb; rock alum, 1/8 lb.; carbonate ammonia, 4 oz.; salt of tartar, 4 oz. Pulverize all together and incorporate thoroughly. Use by powdering all over the iron while hot, then plunging in a cold liquid made as follows: Soft water, 10 gals.; salt, 1 peck; oil of vitrol, 1/2 pint; saltpetre, 1/2 lb.; prusiate of potash, 1/4 lb; cyanide of potash, 1/4 lb. Heat the iron a cherry red, and if not sufficiently hard repeat the process.

Tinning Surfaces—Articles of Brass or Copper boiled in a solution of staunate of potassa, mixed with turnings or scrapings of tin, in a few moments become covered with a firmly attached layer of fine tin.

Weights of Aluminum, Brass and Copper Sheets

APPROXIMATE—POUNDS PER SQUARE FOOT

American Wire or Brown & Sharpe Gauge No.	THICKNESS Inch	S. A. E. ALUMINUM ALLOYS Nos. 26-27	S. A. E. ALUMINUM ALLOYS No. 28	ALUMINUM Commercially Pure 99 to 99.4 per cent	COMMERCIAL HIGH BRASS	COPPER Cold-Rolled and Annealed
0000	0.4600	5.680	6.410	6.490	20.270	21.270
000	0.4096	5.950	5.710	5.780	18.050	18.940
00	0.3648	5.290	5.090	5.140	16.070	16.870
0	0.3249	4.720	4.530	4.580	14.320	15.030
1	0.2893	4.200	4.030	4.080	12.750	13.380
2	0.2576	3.738	3.591	3.632	11.350	11.910
3	0.2294	3.229	3.198	3.234	10.110	10.610
4	0.2043	2.964	2.848	2.880	9.000	9.450
5	0.1819	2.640	2.536	2.565	8.010	8.410
6	0.1620	2.351	2.258	2.284	7.140	7.490
7	0.1443	2.094	2.012	2.034	6.360	6.670
8	0.1285	1.865	1.792	1.812	5.660	5.940
9	0.1141	1.660	1.595	1.613	5.040	5.290
10	0.1019	1.479	1.420	1.437	4.490	4.713
11	0.0907	1.316	1.264	1.779	3.996	4.195
12	0.0808	1.172	1.126	1.139	3.560	3.737
13	0.0742	1.045	1.004	1.015	3.172	3.330
14	0.0641	0.930	0.894	0.904	2.824	2.965
15	0.0571	0.829	0.796	0.805	2.516	2.641
16	0.0508	0.737	0.708	0.716	2.238	2.349
17	0.0453	0.637	0.631	0.639	1.996	2.095
18	0.0403	0.585	0.562	0.568	1.776	1.864
19	0.0359	0.5210	0.5010	0.5060	1.5820	1.6600
20	0.0320	0.4640	0.4460	0.4510	1.4100	1.4800
21	0.0285	0.4140	0.3970	0.4020	1.2560	1.3180
22	0.0253	0.3671	0.3527	0.3567	1.1150	1.1700
23	0.0226	0.3280	0.3150	0.3186	0.9960	1.0450
24	0.0201	0.2917	0.2802	0.2834	0.8860	0.9300
25	0.0179	0.2597	0.2495	0.2524	0.7890	0.8280
26	0.0159	0.2307	0.2216	0.2242	0.7010	0.7350
27	0.0142	0.2060	0.1980	0.2002	0.6260	0.6570
28	0.0126	0.1828	0.1756	0.1776	0.5550	0.5830
29	0.0113	0.1640	0.1575	0.1593	0.4980	0.5230
30	0.0100	0.1451	0.1394	0.1410	0.4406	0.4625
31	0.0089	0.1296	0.1245	0.1259	0.3935	0.4130
32	0.0080	0.1154	0.1108	0.1121	0.3503	0.3677
33	0.0071	0.1027	0.0987	0.0998	0.3119	0.3274
34	0.0063	0.0914	0.0878	0.0888	0.2776	0.2914
35	0.0036	0.0814	0.0782	0.0791	0.2472	0.2595
36	0.0050	0.0726	0.0697	0.0705	0.2203	0.2312
37	0.0045	0.0646	0.0620	0.0627	0.1961	0.2058
38	0.0040	0.0576	0.0553	0.0560	0.1749	0.1836
39	0.0035	0.0512	0.0492	0.0498	0.1555	0.1633
40	0.0031	0.0456	0.0438	0.0443	0.1383	0.1452

Copper Sheets can be Obtained in Fractional Inch Thickness, Varying by Sixteenths of an inch from 1 16″ to 2″.

ALUMINUM

Aluminum is a soft and ductile metal of comparatively high tensile strength, and it is therefore peculiarly adapted for such automobile and machinery parts as require lightness and strength. The metal in a molten condition, however, oxidizes quite readily, and this point, aside from expansion and contraction, is our chief concern in the welding of this metal. By referring to our table of melting points of metals we find that aluminum melts at approximately 1200 Fahrenheit, almost half of the temperature required to melt cast iron, and by referring to our tables on heat conductivity and co-efficients of linear expansion of metals we find that aluminum conducts heat almost three times as readily as iron, as well as has a 50 per cent greater shrinkage.

Shield's Brass and Bronze Bushing Table in All Sizes

Length	Outside Diam.	Solid Bushing	Cored Bushing	Thickness of Walls	Length	Outside Diam.	Solid Bushing	Cored Bushing	Thickness of Walls	Length	Outside Diam.	Solid Bushing	Cored Bushing	Thickness of Walls	Length	Outside Diam.	Solid Bushing	Cored Bushing	Thickness of Walls
12	1	1	1/2	1/4	12	2 1/4	2 1/4	3/4	3/4	12	3	"	1 1/2	3/4	12	3 5/8	"	2 1/8	3/4
12	1 1/8	1 1/8	1/2	5/16	12	2 1/4	"	7/8	11/16	12	3	"	1 5/8	11/16	12	3 5/8	"	2 1/4	11/16
12	1 1/8	"	5/8	1/4	12	2 1/4	"	1	5/8	12	3	"	1 3/4	5/8	12	3 5/8	3 5/8	2 3/8	5/8
12	1 1/4	1 1/4	1/2	3/8	12	2 1/4	"	1 1/8	9/16	12	3	"	1 7/8	9/16	12	3 5/8	"	2 1/2	9/16
12	1 1/4	"	5/8	5/16	12	2 1/4	"	1 1/4	1/2	12	3	"	2	1/2	12	3 5/8	"	2 5/8	1/2
12	1 1/4	"	3/4	1/4	12	2 1/4	"	1 3/8	7/16	12	3 1/8	3 1/8	1 1/8	1	12	3 5/8	"	2 3/4	7/16
12	1 3/8	1 3/8	1/2	7/16	12	2 1/4	"	1 1/2	3/8	12	3 1/8	"	1 1/4	15/16	12	3 3/4	3 3/4	1 1/8	1 5/16
12	1 3/8	"	5/8	3/8	12	2 1/4	"	1 5/8	5/16	12	3 1/8	"	1 3/8	7/8	12	3 3/4	"	1 1/4	1 1/4
12	1 3/8	"	3/4	5/16	12	2 3/8	2 3/8	1	11/16	12	3 1/8	"	1 1/2	13/16	12	3 3/4	"	1 3/8	1 3/16
12	1 3/8	"	7/8	1/4	12	2 3/8	"	1 1/8	5/8	12	3 1/8	"	1 5/8	3/4	12	3 3/4	"	1 1/2	1 1/8
12	1 1/2	1 1/2	1/2	1/2	12	2 3/8	"	1 1/4	9/16	12	3 1/8	"	1 3/4	11/16	12	3 3/4	"	1 5/8	1 1/16
12	1 1/2	"	5/8	7/16	12	2 3/8	2 3/8	1 3/8	1/2	12	3 1/8	"	1 7/8	5/8	12	3 3/4	"	1 3/4	1
12	1 1/2	"	3/4	3/8	12	2 3/8	"	1 1/2	7/16	12	3 1/8	"	2	9/16	12	3 3/4	"	1 7/8	15/16
12	1 1/2	"	7/8	5/16	12	2 3/8	"	1 5/8	3/8	12	3 1/4	3 1/4	1 1/8	1 1/16	12	3 3/4	"	2	7/8
12	1 1/2	"	1	1/4	12	2 3/8	"	1 3/4	5/16	12	3 1/4	"	1 1/4	1	12	3 3/4	"	2 1/8	13/16
12	1 5/8	1 5/8	1/2	9/16	12	2 1/2	2 1/2	1	3/4	12	3 1/4	"	1 3/8	15/16	12	3 3/4	"	2 1/4	3/4
12	1 5/8	"	5/8	1/2	12	2 1/2	"	1 1/8	11/16	12	3 1/4	"	1 1/4	7/8	12	3 3/4	"	2 3/8	11/16
12	1 5/8	"	3/4	7/16	12	2 1/2	"	1 1/4	5/8	12	3 1/4	"	1 5/8	13/16	12	3 3/4	"	2 1/2	5/8
12	1 5/8	"	7/8	3/8	12	2 1/2	"	1 3/8	9/16	12	3 1/4	"	1 3/4	3/4	12	3 3/4	"	2 5/8	9/16
12	1 5/8	"	1	5/16	12	2 1/2	"	1 1/2	1/2	12	3 1/4	"	1 7/8	11/16	12	3 3/4	"	2 3/4	1/2
12	1 5/8	"	1 1/8	1/4	12	2 1/2	"	1 5/8	7/16	12	3 1/4	"	2	5/8	12	3 7/8	3 7/8	1 1/4	1 5/16
12	1 3/4	1 3/4	1/2	5/8	12	2 1/2	"	1 3/4	3/8	12	3 1/4	"	2 1/8	9/16	12	3 7/8	"	1 3/8	1 1/4
12	1 3/4	"	5/8	9/16	12	2 1/2	"	1 7/8	5/16	12	3 3/8	3 3/8	1 1/8	1 1/8	12	3 7/8	"	1 1/2	1 3/16
12	1 3/4	"	3/4	1/2	12	2 5/8	2 5/8	1	13/16	12	3 3/8	"	1 1/4	1 1/16	12	3 7/8	"	1 5/8	1 1/8
12	1 3/4	"	7/8	7/16	12	2 5/8	"	1 1/8	3/4	12	3 3/8	"	1 3/8	1	12	3 7/8	"	1 3/4	1 1/16
12	1 3/4	"	1	3/8	12	2 5/8	"	1 1/4	11/16	12	3 3/8	"	1 1/2	15/16	12	3 7/8	"	1 7/8	1
12	1 3/4	"	1 1/8	5/16	12	2 5/8	"	1 3/8	5/8	12	3 3/8	"	1 5/8	7/8	12	3 7/8	"	2	15/16
12	1 3/4	"	1 1/4	1/4	12	2 5/8	"	1 1/2	9/16	12	3 3/8	"	1 3/4	13/16	12	3 7/8	"	2 1/8	7/8
12	1 7/8	1 7/8	5/8	5/8	12	2 5/8	"	1 5/8	1/2	12	3 3/8	"	1 7/8	3/4	12	3 7/8	"	2 1/4	13/16
12	1 7/8	"	3/4	9/16	12	2 5/8	"	1 3/4	7/16	12	3 3/8	"	2	11/16	12	3 7/8	"	2 3/8	3/4
12	1 7/8	"	7/8	1/2	12	2 5/8	"	1 7/8	3/8	12	3 3/8	"	2 1/8	5/8	12	3 7/8	"	2 1/2	11/16
12	1 7/8	1 7/8	1	7/16	12	2 5/8	"	2	5/16	12	3 3/8	"	2 1/4	9/16	12	3 7/8	"	2 5/8	5/8
12	1 7/8	"	1 1/8	3/8	12	2 3/4	2 3/4	1	7/8	12	3 1/2	3 1/2	1 1/8	1 3/16	12	3 7/8	"	2 3/4	9/16
12	1 7/8	"	1 1/4	5/16	12	2 3/4	"	1 1/8	13/16	12	3 1/2	"	1 1/4	1 1/8	12	3 7/8	3 7/8	2 7/8	1/2
12	1 7/8	"	1 3/8	1/4	12	2 3/4	"	1 1/4	3/4	12	3 1/2	"	1 3/8	1 1/16	12	4	4	1 1/4	1 3/8
12	2	2	5/8	11/16	12	2 3/4	"	1 3/8	11/16	12	3 1/2	"	1 1/2	1	12	4	"	1 3/8	1 5/16
12	2	"	3/4	5/8	12	2 3/4	"	1 1/2	5/8	12	3 1/2	"	1 5/8	15/16	12	4	"	1 1/2	1 1/4
12	2	"	7/8	9/16	12	2 3/4	"	1 5/8	9/16	12	3 1/2	"	1 3/4	7/8	12	4	"	1 5/8	1 3/16
12	2	"	1	1/2	12	2 3/4	"	1 3/4	1/2	12	3 1/2	"	1 7/8	13/16	12	4	"	1 3/4	1 1/8
12	2	"	1 1/8	7/16	12	2 7/8	2 7/8	1	15/16	12	3 1/2	"	2	3/4	12	4	"	1 7/8	1 1/16
12	2	"	1 1/4	3/8	12	2 7/8	"	1 1/8	7/8	12	3 1/2	"	2 1/8	11/16	12	4	"	2	1
12	2	"	1 3/8	5/16	12	2 7/8	"	1 1/4	13/16	12	3 1/2	"	2 1/4	5/8	12	4	"	2 1/8	15/16
12	2	"	1 1/2	1/4	12	2 7/8	2 7/8	1 3/8	3/4	12	3 1/2	"	2 3/8	9/16	12	4	"	2 1/4	7/8
12	2	"	1 5/8	3/16	12	2 7/8	"	1 1/2	11/16	12	3 5/8	3 5/8	1 1/8	1 1/4	12	4	"	2 3/8	13/16
12	2 1/8	2 1/8	3/4	11/16	12	2 7/8	"	1 5/8	5/8	12	3 5/8	"	1 1/4	1 3/16	12	4	"	2 1/2	3/4
12	2 1/8	"	7/8	5/8	12	2 7/8	"	1 3/4	9/16	12	3 5/8	"	1 3/8	1 1/8	12	4	"	2 5/8	11/16
12	2 1/8	"	1	9/16	12	2 7/8	"	1 7/8	1/2	12	3 5/8	"	1 1/2	1 1/16	12	4	"	2 3/4	5/8
12	2 1/8	"	1 1/8	1/2	12	3	3	1	1	12	3 5/8	"	1 5/8	1	12	4	"	2 7/8	9/16
12	2 1/8	"	1 1/4	7/16	12	3	"	1 1/8	15/16	12	3 5/8	"	1 3/4	15/16	12	4	"	3	1/2
12	2 1/8	"	1 3/8	3/8	12	3	"	1 1/4	7/8	12	3 5/8	"	1 7/8	7/8					
12	2 1/8	"	1 1/2	5/16	12	3	"	1 3/8	13/16	12	3 5/8	"	2	13/16					

International Atomic Weights

	Sym-bol	At. Num-ber	At. Weight	Melting Point C°		Sym-bol	At. Num-ber	At. Weight	Melting Point C°
Aluminum	Al	13	26.97	658.7	Mercury	Hg	80	200.61	−38.85
Antimony	Sb	51	121.76	630.0	Molybdenum	Mo	42	96.0	2535
Argon	A	18	39.944	−189.6	Neodymium	Nd	60	144.27	840
Arsenic	As	33	74.91	Subl.(500)	Neon	Ne	10	20.183	−253
Barium	Ba	56	137.36	850	Nickel	Ni	28	58.69	1452
Beryllium	Be	4	9.02	1280	Nitrogen	N	7	14.008	−210.5
Bismuth	Bi	83	209.00	269.2	Osmium	Os	76	191.5	2700
Boron	B	5	10.82	2000-2500	Oxygen	O	8	16.000	−218
Bromine	Br	35	79.916	−7.3	Palladium	Pd	46	106.7	1549
Cadmium	Cd	48	112.41	320.9	Phosphorus	P	15	31.02	44.2
Calcium	Ca	20	40.07	810	Platinum	Pt	78	195.23	1755
Carbon	C	6	12.000	3500	Potassium	K	19	39.096	62.3
Cerium	Ce	58	140.13	640	Praseodymium	Pr	59	140.92	940
Cesium	Cs	55	132.91	26.4	Radium	Ra	88	225.97	....
Chlorine	Cl	17	35.457	−40	Radon	Rn	86	222	....
Chromium	Cr	24	52.01	1615	Rhodium	Rh	45	102.91	1950
Cobalt	Co	27	58.94	1480	Rubidium	Rb	37	85.44	38.5
Columbium	Cb	41	93.1	1950	Ruthenium	Ru	44	101.7	2450
Copper	Cu	29	63.57	1083	Samarium	Sm	62	150.43	1300-1400
Dysprosium	Dy	66	162.46	....	Scandium	Sc	21	45.10	1200?
Erbium	Er	68	167.64	....	Selenium	Se	34	78.96	217
Europium	Eu	63	152.0	....	Silicon	Si	14	28.06	1420
Fluorine	F	9	19.00	−187	Silver	Ag	47	107.880	960.5
Gadolinium	Gd	64	157.3	....	Sodium	Na	11	22.997	97.5
Gallium	Ga	31	69.72	30.1	Strontium	Sr	38	87.63	900
Germanium	Ge	32	72.60	958	Sulfur	S	16	32.06	112.8
Gold	Au	79	197.2	1063	Tantalum	Ta	73	181.4	2910
Hafnium	Hf	72	178.6		Tellurium	Te	52	127.61	541
Helium	He	2	4.002	−268.8 B.P.	Terbium	Tb	65	159.2	....
Holmium	Ho	67	163.5	....	Thallium	Tl	81	204.39	301.7
Hydrogen	H	1	1.0078	−259	Thorium	Th	90	232.12	1700
Indium	In	49	114.76	155	Thulium	Tm	69	169.4	....
Iodine	I	53	126.92	113.5	Tin	Sn	50	118.70	231.9
Iridium	Ir	77	193.1	2360	Titanium	Ti	22	47.90	1800?
Iron	Fe	26	55.84	1530	Tungsten	W	74	184.0	3400
Krypton	Kr	36	83.7	−169	Uranium	U	92	238.14	near Mo.
Lanthanum	La	57	138.92	810	Vanadium	V	23	50.95	1740
Lead	Pb	82	207.22	327	Xenon	Xe	54	131.3	−140
Lithium	Li	3	6.940	186	Ytterbium	Yb	70	173.04	....
Luthecium	Lu	71	175.0	....	Yttrium	Y	39	88.92	1490
Magnesium	Mg	12	24.32	651	Zinc	Zn	30	65.38	419.4
Manganese	Mn	25	54.93	1230	Zirconium	Zr	40	91.22	2350

WEIGHT OF WIRE

Weight of 100 Lineal Feet

B. W. Gauge	Iron Lbs.	Steel Lbs.	Brass Lbs.	Copper Lbs.
0	30.58	30.92	33.43	35.17
1	25.75	26.04	28.15	29.62
2	21.34	21.57	23.32	24.54
3	18.02	18.22	19.70	20.72
4	15.11	15.28	16.52	17.38
5	12.46	12.59	13.62	14.33
6	11.45	11.57	12.51	13.16
7	9.25	9.35	10.11	10.64
8	7.29	7.37	7.97	8.38
9	6.60	6.68	7.22	7.59
10	4.96	5.02	5.43	5.71
11	4.13	4.18	4.52	4.75
12	3.14	3.18	3.43	3.61
13	2.34	2.36	2.55	2.69
14	1.69	1.71	1.85	1.95
15	1.37	1.39	1.50	1.58
16	1.05	1.06	1.15	1.21
17	.804	.815	.877	.928
18	.612	.622	.674	.704
19	.471	.478	.510	.547
20	.326	.331	.342	.372
21	.271	.274	.293	.310
22	.208	.210	.224	.237
23	.166	.167	.179	.189
24	.128	.129	.138	.147
25	.106	.107	.114	.121
26	.086	.087	.093	.098
27	.068	.069	.073	.078
28	.052	.053	.056	.059
29	.045	.046	.048	.051
30	.038	.039	.041	.044

To Compute the Weight of Cast Metal by the Weight of the Pattern—When made of pine—Multiply the weight of the pattern in pounds by the following multipliers and the product will be the weight of casting: Iron, 14 pounds to the pound of pattern; Brass, 15; Lead, 22; Tin, 14; Zinc, 13.5 pounds.

Weight per Inch

Of round bars of carbon and high speed steel in pounds per linear inch.

Diam. of Bar Inches	Weight of Bar One Inch Long		Diam. of Bar Inches	Weight of Bar One Inch Long		Diam. of Bar Inches	Weight of Bar One Inch Long	
	Carbon Steel	High Speed Steel		Carbon Steel	High Speed Steel		Carbon Steel	High Speed Steel
1/16	.00087	.00098	2 7/16	1.33	1.496	4 13/16	5.15	5.793
1/8	.0035	.0039	2 1/2	1.39	1.563	4 7/8	5.28	5.940
3/16	.0078	.0088	2 9/16	1.46	1.642	4 15/16	5.42	6.097
1/4	.0139	.0156	2 5/8	1.53	1.721	5	5.56	6.255
5/16	.0217	.0244	2 11/16	1.61	1.811	5 1/16	5.70	6.412
3/8	.0313	.0352	2 3/4	1.68	1.890	5 1/8	5.84	6.570
7/16	.0425	.0478	2 13/16	1.76	1.980	5 3/16	5.98	6.727
1/2	.0556	.0625	2 7/8	1.84	2.070	5 1/4	6.13	6.896
9/16	.0703	.0791	2 15/16	1.92	2.160	5 5/16	6.27	7.053
5/8	.0868	.0976	3	2.00	2.250	5 3/8	6.42	7.222
11/16	.105	.118	3 1/16	2.08	2.340	5 7/16	6.57	7.391
3/4	.125	.141	3 1/8	2.17	2.441	5 1/2	6.72	7.560
13/16	.147	.165	3 3/16	2.26	2.542	5 9/16	6.88	7.740
7/8	.170	.191	3 1/4	2.35	2.643	5 5/8	7.03	7.908
15/16	.195	.219	3 5/16	2.44	2.745	5 11/16	7.19	8.088
1	.22	.248	3 3/8	2.53	2.846	5 3/4	7.35	8.268
1 1/16	.25	.281	3 7/16	2.63	2.958	5 13/16	7.51	8.448
1 1/8	.28	.315	3 1/2	2.72	3.060	5 7/8	7.67	8.628
1 3/16	.31	.349	3 9/16	2.82	3.172	5 15/16	7.84	8.820
1 1/4	.35	.397	3 5/8	2.92	3.285	6	8.00	9.000
1 5/16	.38	.427	3 11/16	3.02	3.397	6 1/8	8.34	9.382
1 3/8	.42	.472	3 3/4	3.13	3.521	6 1/4	8.68	9.765
1 7/16	.46	.517	3 13/16	3.23	3.633	6 3/8	9.03	10.16
1 1/2	.50	.562	3 7/8	3.34	3.757	6 1/2	9.39	10.56
1 9/16	.54	.607	3 15/16	3.45	3.881	6 5/8	9.76	10.98
1 5/8	.59	.663	4	3.56	4.005	6 3/4	10.1	11.36
1 11/16	.63	.709	4 1/16	3.67	4.128	6 7/8	10.5	11.81
1 3/4	.68	.765	4 1/8	3.78	4.252	7	10.9	12.26
1 13/16	.73	.821	4 3/16	3.90	4.387	7 1/8	11.3	12.71
1 7/8	.78	.877	4 1/4	4.01	4.511	7 1/4	11.7	13.16
1 15/16	.83	.933	4 5/16	4.13	4.646	7 3/8	12.1	13.61
2	.89	1.001	4 3/8	4.25	4.781	7 1/2	12.5	14.06
2 1/16	.94	1.057	4 7/16	4.38	4.927	7 5/8	12.9	14.51
2 1/8	1.00	1.125	4 1/2	4.50	5.062	7 3/4	13.3	14.96
2 3/16	1.06	1.192	4 9/16	4.63	5.208	7 7/8	13.8	15.52
2 1/4	1.13	1.271	4 5/8	4.75	5.343	8	14.3	16.08
2 5/16	1.19	1.338	4 11/16	4.88	5.490			
2 3/8	1.25	1.406	4 3/4	5.01	5.636			

WEIGHT TABLE Miscellaneous

PER CUBIC FOOT			
Pine, yellow	34	Earth, loose	94
Pine, white	34	Marble, Italian	169
Ash	53	Marble, Vermont	165
Oak, white, dry	54	Mortar	110
Poplar	23	Mud	102
Poplar, white	33	Water, salt	64
Walnut	41	Water, rain	62
Walnut, black	31	Ice	57 1/2
Stone, com.	158	Hay, baled	95
Sand, wet	128	Hay, pressed	25
Brick, com.	102	Coal, L'y'a.	50
Clay	120	Coal, Lehigh	56
		1 gal. kerosene, about 6 1/2 lbs.	

WEIGHT OF FLAT BAR STEEL, PER LINEAL FOOT

		½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1¾	2	2¼	2½	2¾	3	3½
⅛		.213	.266	.320	.372	.426	.479	.530	.585	.640	.745	.850	.955	1.07	1.18	1.28	1.49
3/16		.319	.399	.480	.558	.639	.718	.790	.878	.960	1.12	1.28	1.43	1.60	1.76	1.92	2.24
¼		.425	.533	.640	.743	.852	.958	1.06	1.17	1.28	1.49	1.70	1.91	2.13	2.34	2.56	2.98
5/16		.531	.665	.800	.929	1.06	1.20	1.33	1.46	1.60	1.86	2.13	2.39	2.66	2.92	3.19	3.72
⅜		.638	.798	.960	1.12	1.28	1.43	1.59	1.75	1.91	2.23	2.55	2.87	3.20	3.51	3.83	4.46
7/16		.744	.931	1.12	1.30	1.49	1.67	1.86	2.05	2.23	2.60	2.98	3.35	3.72	4.09	4.46	5.21
½		....	1.07	1.28	1.49	1.70	1.91	2.13	2.34	2.55	2.98	3.40	3.83	4.26	4.68	5.10	5.96
9/16		....	1.20	1.44	1.67	1.91	2.15	2.39	2.63	2.87	3.35	3.83	4.30	4.78	5.26	5.74	6.69
⅝		....	....	1.60	1.86	2.12	2.39	2.66	2.92	3.19	3.72	4.26	4.79	5.32	5.86	6.39	7.44
11/16		....	....	1.76	2.04	2.34	2.63	2.92	3.22	3.51	4.09	4.68	5.26	5.84	6.43	7.01	8.18
¾		....	....	....	2.23	2.55	2.86	3.19	3.50	3.83	4.46	5.10	5.74	6.40	7.02	7.65	8.92
13/16		....	....	....	2.41	2.76	3.11	3.45	3.80	4.14	4.83	5.53	6.22	6.91	7.60	8.29	9.67
⅞		....	....	....	....	2.98	3.34	3.72	4.09	4.46	5.21	5.96	6.70	7.46	8.19	8.94	10.42
15/16		....	....	....	....	3.19	3.59	3.98	4.38	4.78	5.58	6.38	7.17	7.97	8.77	9.56	11.20
1		....	....	....	....	....	3.82	4.25	4.68	5.10	5.96	6.80	7.66	8.52	9.36	10.20	11.92

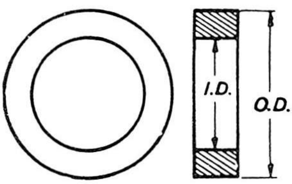
INFORMATION FOR USE OF WEIGHT TABLES

Rings—To obtain the weight of a ring, subtract the weight per inch of the inside diameter from the weight per inch of the outside diameter (as obtained from the table), and multiply this remainder by the width.

Example:

Let O. D. = 10″
I. D. = 6″
Width = 3″
From table 10″ = 22.20
6″ = 8.00

14.20 x 3 = 42.60 lbs.

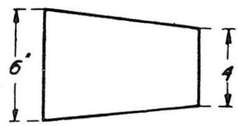


Tapers—Add together the weights per inch (as given in table) of the smaller diameter, larger diameter and that for the diameter equal to the sum of the smaller and larger diameter.

Then divide this total by 6.

Example:

	6″ diam. weighs	8.00
	4″ diam. weighs	3.56
(6+4)	10″ diam. weighs	22.20
		6)33.76
		5.63



which multiplied by the length in inches gives the weight of the tapered section.

To obtain the weights of squares, octagons or hexagons from the table, figure as rounds and then multiply the result by the following factors:

Squares, 1.274; Hexagons, 1.103; Octagons, 1.054; Decagons, 1.034.

Example:—The weight per inch of a 6″ hexagon bar will be:—

From table 6″ = 8.00
x1.103

8.824 lbs. per 1″ of length.

The weight table gives the weight per inch of length for the various diameters.

The weight table is based on one cubic inch of steel weighing 0.283 pounds.

When weight tables cannot be used, weights must be based on cubic inch of steel weighing 0.283 pounds.

TABLE FOR ESTIMATING QUANTITY OF NAILS

Material	Size of Nail	Lbs. Required
1000 Shingles	4d	5
1000 Laths	3d	7
1000 Square Feet Beveled Siding	6d	18
1000 " " Sheathing	8d	20
1000 " " "	10d	25
1000 " " Flooring	8d	30
1000 " " "	10d	40
1000 " " Studding	10d	15
1000 " " Furring 1 x 2 in.	10d	10
1000 " " Finished Flooring, ⅞ in.	8d to 10d Fin.	20
1000 " " " " 1⅛ in.	10d Fin.	30

LONG MEASURE (Measures of Length)

Ins.		Feet		Yards		Fathoms		Rods		Furlongs		Mile
12	=	1										
36	=	3	=	1	=							
72	=	6	=	2	=	1						
198	=	16½	=	5½	=	2¾	=	1				
7920	=	660	=	220	=	110	=	40	=	1		
63360	=	5280	=	1760	=	880	=	320	=	8	=	1

6080.26 Feet = 1.15 Statute Miles = 1 Nautical Mile or Knot.

WEIGHT, ONE SQUARE FOOT OF METALS

Thickness	Wrought Iron	Cast Iron	Steel	Copper	Brass	Lead
In.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/16	2.50	2.34	2.55	2.89	2.63	3.71
⅛	5.00	4.69	5.10	5.79	5.26	7.41
3/16	7.50	7.03	7.65	8.68	7.89	11.1
¼	10.0	9.38	10.2	11.6	10.5	14.8
5/16	12.5	11.7	12.8	14.5	13.2	18.5
⅜	15.0	14.1	15.3	17.4	15.8	22.2
7/16	17.5	16.4	17.9	20.3	18.4	25.9
½	20.0	18.7	20.4	23.2	21.1	29.7

Approximate Weight and Strength of Cordage

Circumference in inches	Diameter in inches	Weight of 100 fathoms of 600 feet in lbs.	Weight of 100 fathoms Tarred in lbs.	Strength of New Ropes in lbs.	No. of feet in 1 lb.
6 thd.	3/16 in.	12	17	540	50 feet
9 "	¼ "	18	24	780	33 " 4 in.
12 "	5/16 "	24	34	1000	25 "
15 "	⅜ "	30	45	1280	20 "
1¼ in.	7/16 "	37	50	1562	17 " 8 in.
1½ "	½ "	46	55	2250	13 "
1¾ "	9/16 "	65	85	3062	9 " 3 "
2 "	⅝ "	80	100	4000	7 " 6 "
2¼ "	¾ "	98	125	5000	6 "
2½ "	13/16 "	120	155	6250	5 "
2¾ "	⅞ "	142	190	7500	4 " 3 "
3 "	1 "	170	225	9000	3 " 6 "
3¼ "	1 1/16 "	200	265	10500	3 "
3½ "	1⅛ "	230	300	12250	2 " 7 "
3¾ "	7¼ "	271	350	14000	2 " 3 "
4 "	1 5/16 "	310	405	16000	1 " 11 "
4¼ "	1⅜ "	346	455	18062	1 " 8 "
4½ "	1½ "	390	510	20250	1 " 6 "
4¾ "	1 9/16 "	435	575	22500	1 " 5 "
5 "	1⅝ "	480	640	25000	1 " 3 "
5½ "	1¾ "	581	775	30250	1 "
6 "	2 "	678	930	36000	10⅜ "

Note that strength is given for new rope. For safe working should be divided by 10.

WEIGHT OF CASTING OF DIFFERENT METALS PER POUND OF WOOD PATTERN

	Cast Iron	Copper	Gun Metal	Yell. Brass	Zinc	Aluminum
Mahogany	8 lb.	10 lb.	10 lb.	9.8 lb.	8 lb.	3 lb.
White pine	14 "	18 "	17.8 "	17.5 "	14.5 "	6 "
Yellow pine	13 "	16 "	16 "	15.5 "	12.6 "	5.5 "
Cedar	11.5 "	14.5 "	14.5 "	14 "	11.4 "	4.6 "
Maple	10 "	12.5 "	12.4 "	12 "	9.8 "	4.2 "
Cherry	9 "	12 "	12 "	11.8 "	9.4 "	4 "

SHRINKAGE OF CASTINGS PER FOOT — Yellow brass, $\frac{10}{64}$; gun metal, $\frac{9}{64}$; copper, $\frac{3}{16}$; zinc, $\frac{5}{16}$; cast iron, $\frac{1}{8}$; aluminum, $\frac{7}{32}$; lead, $\frac{5}{32}$. In thin brass = $\frac{3}{16}$ in.
In large cylinders = $\frac{3}{32}$ in. In small cylinders = $\frac{1}{16}$ in. In tin = $\frac{1}{4}$ in.
In bismuth = $\frac{5}{32}$ in. In beams and girders = $\frac{1}{10}$ in. In steel = $\frac{1}{4}$ in.

ESTIMATING WEIGHTS OF DIFFERENT METALS IN CUBIC INCH AND CUBIC FOOT FOR FOUNDRY

METALS	WEIGHT PER CU. IN.	WEIGHT PER CU. FT.
Iron	.263 lbs.	451 lbs.
Steel	.288 lbs.	499 lbs.
Brass	.3 lbs.	524 lbs.
Lead	.41 lbs.	708 lbs.
Copper	.32 lbs.	537 lbs.
Tin	.266 lbs.	451 lbs.

For a rough approximation, weighing the pattern and multiplying its weight in pounds by 16 is of course the easiest and quickest way and is the one most used by foundry men in estimating the amount of iron to be melted for a heat or a certain casting. The following constants may be used as multipliers for the metals named when cast:

WEIGHT OF WOOD PER FOOT

The weights in pounds, of various kinds of woods (commercially known as "dry" timber), per foot-board measure as follows: White Pine, 1.98; Spanish Mahogany, 4.42; Honduras Mahogany, 3; Poplar, 3.25; Washington Fir, 2.65; Cedar, 1.93; California Spruce, 2.08; Cherry, 3.5; Maple, 4.08.

Use Kerosene Oil (coal oil) for drilling or turning aluminum.

TEMPERING LIQUID

Saltpetre	2 ounces
Sal-ammoniac	2 ounces
Alum	2 ounces
Salt	1½ pounds
Soft Water	3 gallons

Never heat over cherry red. Draw no temper.

AVOIRDUPOIS OR COMMERCIAL WEIGHT

1 gross or long ton = 2240 pounds.
1 net or short ton = 2000 pounds.
1 pound = 16 ounces = 7000 grains.
1 ounce = 16 drachms = 437.5 grains.

The following measures for weight are now seldom used in the United States:
1 hundred-weight = 4 quarters = 112 pounds (1 gross or long ton = 20 hundred-weights); 1 quarter = 28 pounds; 1 stone = 14 pounds; 1 quintal = 100 pounds.

CIRCULAR AND ANGULAR MEASURE

60 seconds (″) = 1 minute (′)
60 minutes = 1 degree (°)
360 degrees = 1 circumference (C)

APOTHECARIES' WEIGHT

20 grains (gr.) = 1 scruple (sc., or).
3 scruples = 1 dram (dr., or ʒ).
8 drams = 1 ounce (oz., or ℥).
12ounces = 1 pound (lb., or ℔).

WEIGHT PER BUSHEL OF DIFFERENT GRAINS, ETC.

Barley	48 pounds
Beans	63 pounds
Buckwheat	46 pounds
Blue Grass Seed	14 pounds
Corn	56 pounds
Corn Meal	50 pounds
Clover Seed	60 pounds
Dried Apples	22 pounds
Dried Peaches	33 pounds
Flax Seed	56 pounds
Hemp Seed	48 pounds
Oats	32 pounds
Peas	64 pounds
Rye	56 pounds
Salt	80 pounds
Timothy Seed	45 pounds
Wheat	60 pounds
Potatoes (heaped)	60 pounds

MISCELLANEOUS UNITS OF LENGTH

1-mil = 0.001 inch
1-hand = 4 inches
1-span = 9 inches
1-fathom = 6 feet
1-link = 0.66 feet
1-rod = 25 links
1-Surveyor's or Gunter's chain = 100 feet
1-knot (nautical mile) = 1.1516 statute miles
1-furlong = 40 rods
1-pole (British) = 5.5 yards
1-British fathom = 6.08 feet
1-toise = 6 Paris feet
1-Paris foot (pied) = 12 Paris inches
12-Paris inches = 0.324839 meter
1-Paris line (ligne) = 0.225583 centimeter
1-Light year = 5.9 x 10^{12} miles
1-point (type size) = 1/72 or 0.08333 inch
1-cubit = 18 inches

MEASURES OF PRESSURE

1 pound per square inch = 144 pounds per square foot = 0.068 atmosphere = 2.042 inches of mercury at 62 degrees F. = 27.7 inches of water at 62 degrees F. = 2.31 feet of water at 62 degrees F.

1 atmosphere = 30 inches of mercury at 62 degrees F. = 14.7 pounds per square inch = 2116.3 pounds per square foot = 33.95 feet of water at 62 degrees F.

1 foot of water at 62 degrees F. = 62.355 pounds per square foot = 0.433 pound per square inch.

1 inch of mercury at 62 degrees F. = 1.132 foot of water = 13.58 inches of water = 0.491 pound per square inch.

TROY WEIGHT, USED FOR WEIGHING GOLD AND SILVER

1 pound = 12 ounces = 5760 grains.
1 ounce = 20 pennyweights = 480 grains.
1 pennyweight = 24 grains.
1 carat (used in weighing diamonds) = 3.086 grains.
1 grain Troy = 1 grain avoirdupois = 1 grain apothecaries' weight.

NAUTICAL MEASURE

The following measures of length are also used occasionally: 1 mil equals 0.001 inch. 1 fathom equals 2 yards equals 6 feet. 1 rod equals 5.5 yards equals 16.5 feet. 1 hand equals 4 inches. 1 span equals 9 inches. 1 mile equals 1760 yards equals 5280 feet. 1 league equals 3 nautical miles. 1 nautical mile (knot) equals 6080.26 feet equals 1.1516 statute mile. One degree at the equator equals 60 nautical miles equals 69.168 statute miles. 360 degrees equals 21,600 nautical miles equals 24,874.5 statute miles equal circumference of earth at the equator.

MEASURE USED FOR DIAMETERS AND AREAS OF ELECTRIC WIRES

1 circular inch = area of circle 1 inch in diameter = 0.7854 square inch.
1 circular inch = 1,000,000 circular mils.
1 square inch = 1.2732 circular inch = 1,273,239 circular mils.
A circular mil is the area of a circle 0.001 inch in diameter.

SHIPPING MEASURE

For measuring entire internal capacity of a vessel:
1 register ton = 100 cubic feet.
For measurement of cargo:
1 U. S. shipping ton = 40 cubic feet = 32.143 U. S. bushels = 31.16 Imperial bushels.
British shipping ton = 42 cubic feet = 33.75 U. S. bushels = 32.72 Imperial bushels.

CUBIC MEASURE

1,728 cubic in. = 1 cu. ft.
27 cubic ft. = 1 cubic yard
128 cu. ft. = 1 cord (wood)
40 cu. ft. = 1 ton (shpg.)
2,150.42 cubic inches = 1 standard bushel
268.8 cubic inches = 1 standard gallon
1 cubic foot = about four-fifths of a bushel

SURVEYORS' MEASURE

1 Link = 7.92 inches
1 Rod (or Pole) = 25 links = 16½ feet
1 Chain = 100 links = 4 rods = 66 feet
1 Furlong = 40 rods = 10 chains = ⅛ mile
1 Mile = 320 rods = 5,280 feet
1 Acre = 160 square rods = 43,560 sq. feet
1 Square Mile = 640 acres

1 cord of wood = 4 × 4 × 8 feet = 128 cubic feet.
1 perch of masonry = 16½ × 1½ × 1 foot = 24¾ cubic feet.

SQUARE MEASURE

1 square mile = 640 acres = 6400 square chains.
1 acre = 10 square chains = 4840 square yards = 43,560 square feet.
1 square chain = 16 square rods = 484 square yards = 4356 square feet.
1 square rod = 30.25 square yards = 272.25 square feet = 625 square links.
1 square yard = 9 square feet.
1 square foot = 144 square inches.

An acre is equal to a square, the side of which is 208.7 feet.

DRY MEASURE

1 bushel (U. S. or Winchester struck bushel) = 1.2445 cubic foot = 2150.42 cubic inches.
1 bushel = 4 pecks = 32 quarts = 64 pints
1 peck = 8 quarts = 16 pints.
1 quart = 2 pints.
1 heaped bushel = 1¼ struck bushel.
1 cubic foot = 0.8036 struck bushel.
1 British Imperial bushel = 8 Imperial gallons = 1.2837 cubic foot = 2218.19 cubic inches.

LIQUID OR WINE MEASURE

The U. S. Standard Gallon measures 231 Cubic Inches, or 8.33888 Pounds avoirdupois of pure water, at about 39.85 degrees Fahr., the Barometer at 30 inches.

Gills	Pints	Quarts	Gallons	Tierces	Hogsheads	Puncheons	Pipes	Tun	Cubic Inches
4 =	1 =								28.375
8 =	2 =	1 =							57.75
32 =	8 =	4 =	1 =						231.
1344 =	336 =	168 =	42 =	1					
2016 =	504 =	252 =	63 =	1⅓ =	1				
2488 =	672 =	336 =	84 =	2 =	1⅓ =	1			
4032 =	1008 =	504 =	126 =	3 =	2 =	1½ =	1		
8064 =	2016 =	1008 =	252 =	6 =	4 =	3 =	2 =	1	

A Cubic Foot contains 7½ Gallons.
The British Imperial Gallon contains 277.27 Cubic inches and = 1.2 U. S. Gallons.

APOTHECARIES' MEASURE.

60 minims (or drops), m	= 1 fluid dram, f ʒ.
8 fluid drams	= 1 fluid ounce, f ℥.
16 fluid ounces	= 1 pint (*octarius*), O.
8 pints	= 1 gallon (*congius*).

CLOTH MEASURE.

2¼ in.	= 1 nail, *na.*
4 na. = 9 inches	= 1 quarter, *qr.*
4 qr. = 36 inches	= 1 yard, *yd.*
3 qr. = 27 inches	= 1 ell Flemish.
5 qr. = 45 inches	= 1 ell English.
6 qr. = 54 inches	= 1 ell French.
37.2 in.	= 1 ell Scotch.

NUMBERS.

12 units	= 1 dozen.
12 dozen	= 1 gross.
12 gross	= 1 great gross.
20 units	= 1 score.

PAPER.

24 sheets	= 1 quire.
10½ quires	= 1 token.
20 quires	= 1 ream.

TIME.

60 seconds	= 1 minute.
60 minutes	= 1 hour.
24 hours	= 1 day.
7 days	= 1 week.
2 weeks	= 1 fortnight.
4 weeks	= 1 month.
13 months, 1 day, 6 hours, or 365 days, 6 hours	= 1 Julian year.
12 calendar months	= 1 year.

The length of the *astronomical year* is about 365¼ days, or 365 days, 5 hours, 48 minutes, 46 seconds. As the *common year* is 365 days, it becomes necessary once in every four years to add a day to the year, making the *leap year* of 366 days.

Every year whose number is divisible by 4 without a remainder is a leap year, excepting the full centuries, which to be leap years must be divisible by 400 without a remainder; 1900, therefore, was not a leap year.

January, March, May, July, August, October, and December contain 31 days.

April, June, September, and November contain 30 days. February contains 28 days, except in leap years, when it contains 29 days.

LINEAR MEASURE.

3 barleycorns, or ...	1 inch (in.)
13 lines, or	1 inch (in.)
72 points, or	1 inch (in.)
1,000 mils (mi.)	1 inch (in.)
3 inches	1 palm
4 inches	1 hand
9 inches	1 span
12 inches	1 foot (ft.)
18 inches	1 cubit
3 feet	1 yard (yd.)
2½ feet	1 military pace
5 feet	1 geometrical pace
2 yards	1 fathom
5½ yards	1 rod, pole, or perch
66 feet, or	1 Gunter's chain
4 rods	1 Gunter's chain
40 poles, or	1 furlong (fur.)
220 yards	1 furlong (fur.)
8 furlongs, or	1 mile
1,760 yards, or	1 mile
5,280 feet	1 mile
3 miles	1 league

175 lbs. troy .... = 144 lbs. AVOIRDUPOIS

The Imperial Standard Measure is used by British pharmacists. Its denominations and their relative value are:

Gal.	Quarts.	Pints.	F. Oz.	F. Dr.	Minims
1 =	4 =	8 =	160 =	1,280 =	76,800
	1 =	2 =	40 =	320 =	19,200
		1 =	20 =	160 =	9,600
			1 =	8 =	480
				1 =	60

The relative value of United States Apothecaries' and British Imperial Measures is as follows:

U. S. Apothecaries' Measure.	Imperial Measure.	Pints.	F. Oz.	F. Dr.	Minims
1 Gallon	= .83311 Gallon, or	6	13	2	22.85
1 Pint	= .83311 Pint, or		16	5	17.86
1 Fl. Oz.	= 1.04139 Fl. Oz., or		1	0	19.86
1 Fl. Dr.	= 1.04139 Fl. Dr. or			1	2.48
1 Minim	= 1.04139 Minim, or				1.04

THE METRIC SYSTEM.

MEASURES FOR WOOD.

1 centistere	= 0.01 stere	= .353 cubic feet.
1 decistere	= 0.1 stere	= 3.53 cubic feet.
1 stere	= 1 cubic meter	= 35.316 cubic feet. = .2759 cord.
1 decastere	= 10 steres	= 13.079 cubic yards.

(Continued on top of next page.)

LONG MEASURE

Millimeters	×	.03937	=	inches
Millimeters	÷	25.4	=	inches
Centimeters	×	.3937	=	inches
Centimeters	÷	2.54	=	inches
Meters	=	39.37	=	inches (Act of Congress)
Meters	×	3.281	=	feet
Meters	×	1.094	=	yards
Kilometers	×	.621	=	miles
Kilometers	÷	3280.7	=	feet
Kilometers	÷	1.6093	=	miles

LIQUID MEASURE

Liters	×	61.022	=	cubic inches (Act of Congress)
Liters	×	33.84	=	fluid ounces (U. S. Phar.)
Liters	×	.2642	=	gallons (231 cubic inches)
Liters	÷	3.78	=	gallons (231 cubic inches)
Liters	÷	28.316	=	cubic feet
Hectoliters	×	3.531	=	cubic feet
Hectoliters	×	2.84	=	bushels (2150.42 cubic inches)
Hectoliters	×	.131	=	cubic yards
Hectoliters	+	26.42	=	gallons (231 cubic inches)

SQUARE MEASURE

Square millimeters	×	.0015	=	square inches
Square millimeters	+	645.1	=	square inches
Square centimeters	×	.155	=	square inches
Square centimeters	+	6.451	=	square inches
Square meters	×	10.764	=	square feet
Square kilometers	×	247.1	=	acres
Hectares	×	2.471	=	acres

CUBIC MEASURE

Cubic centimeters	÷	16.383	=	cubic inches
Cubic centimeters	÷	3.69	=	fluid drachms (U. S. P.)
Cubic centimeters	÷	29.57	=	fluid ounce (U. S. P.)
Cubic meters	×	35.315	=	cubic feet
Cubic meters	×	1.308	=	cubic yards
Cubic meters	×	264.2	=	gallons (231 cubic inches)

WEIGHTS

Grammes	×	15.432	=	grains (Act of Congress)
Grammes	×	981.	=	dynes
Grammes (water)	+	29.57	=	fluid ounces
Grammes	÷	28.35	=	ounces avoirdupois
Grammes per cubic centimeter	+	27.7	=	pounds per cubic inch
Joule	×	.7373	=	foot pounds
Kilograms	×	2.2046	=	pounds
Kilograms	×	35.3	=	ounces avoirdupois
Kilograms	+	1102.3	=	tons (2,000 pounds)
Kilograms	× . per square centimeter	14.223	=	pounds per square inch

Metric Conversion Tables

U. S. to Metric

Linear

1 inch = 25.4001 millimeters.
1 foot = 0.304801 meters
1 yard = 0.914402 meters.
1 mile = 1.60935 kilometers.

Square

1 square inch = 6.452 square centimeters.
1 square foot = 9.290 square decimeters.
1 square yard = 0.836 square meters.

Cubic

1 cubic inch = 16.387 cubic centimeters.
1 cubic foot = 0.02832 cubic meters.
1 cubic yard = 0.765 cubic meters.

Weight

1 grain = 64.7989 milligrammes.
1 avoirdupois ounce = 28.3495 grammes.
1 troy ounce = 31.10348 grammes.
1 avoirdupois pound = 0.45359 kilogrammes.

Capacity

1 fluid drachm = 3.70 cubic centimeters.
1 fluid ounce = 29.57 milliliters.
1 quart = 0.94636 liters.
1 gallon = 3.78544 liters.

Metric to U. S.

Linear

1 meter = 39.3700 inches.
1 meter = 3.28083 feet.
1 meter = 1.09361 yards.
1 kilometer = 0.62137 miles.

Square

1 square centimeter = 0.1550 square inches.
1 square meter = 10.7640 square feet.
1 square meter = 1.196 square yards.

Cubic

1 cubic centimeter = 0.0610 cubic inches.
1 cubic meter = 35.314 cubic feet.
1 cubic meter = 1.308 cubic yards.

Weight

1 milligramme = 0.01543 grains.
1 kilogramme = 15432.36 grains.
1 hectogramme = 3.5274 avoirdupois ounces.
1 kilogramme = 2.20462 avoirdupois pounds.

Capacity

1 milliliter = 0.27 fluid drachms.
1 centiliter = 0.338 fluid ounces.
1 liter = 1.0567 quarts.
1 dekaliter = 2.6417 gallons.

MEASURES OF CAPACITY

Metric Denominations and Values							Equivalents in Denominations in use		
Names		No. Liters		Cubic Measure			Dry Measure		Wine Measure
Kiloliter	=	1,000	=	1 cubic meter	=		1.308 cubic yards	=	264.17 gallons
Hectoliter	=	100	=	.1 cubic meter	=		2 bush. 3.35 pecks	=	26.417 gallons
Decaliter	=	10	=	10 c. decimeters	=		9.08 quarts	=	2.6417 gallons
Liter	=	1	=	1 c. decimeter	=		0.908 quart	=	1.0567 quarts
Deciliter	=	.1	=	.1 c. decimeter	=		6.1022 cubic inches	=	0.845 gill
Centiliter	=	.01	=	10 c. centimeters	=		0.6102 cubic inch	=	0.338 fluid oz.
Milliliter	=	.001	=	1 c. centimeter	=		0.061 cubic inch	=	0.27 fluid dr.

Miscellaneous Metric System

1 kilogram per meter = .6720 pounds per foot.
1 gram per square millimeter = 1.422 pounds per square inch.
1 kilogram per square meter = 0.2084 pounds per square foot.
1 kilogram per cubic meter = .0624 pounds per cubic foot.
1 degree centigrade = 1.8 degrees Fahrenheit.
1 pound per foot = 1.488 kilograms per meter.
1 pound per square foot = 4.882 kilograms per square meter.
1 pound per cubic foot = 16.02 kilograms per cubic meter.
1 degree Fahrenheit = .5556 degrees centigrade.
1 Calorie (French Thermal Unit) = 3.968 B. T. U. (British Thermal Unit).
1 Horse Power = { 33,000 foot pounds per minute.
746 Watts. }
1 Watt (Unit of Electrical Power) = { .00134 Horse Power.
44.22 foot pounds per minute. }
1 Kilowatt = { 1000 Watts.
1.34 Horse Power
44,220 foot pounds per minute. }

STRENGTH OF MATERIALS

Ultimate Strength of Common Metals: Pounds Per Square Inch				
Material	Tension	Compression	Shear	Medulus o Elasticity
Aluminum	15,000	12,000	12,000	11,000,000
Brass, cast	24,000	30,000	36,000	9,000,000
Bronze, gun-metal	32,000	20,000	——	10,000,000
Bronze, manganese	60,000	120,000	——	——
Bronze, phosphor	50,000	——	——	14,000,000
Copper, cast	24,000	40,000	30,000	10,000,000
Copper Wire, annealed	36,000	——	——	15,000,000
Copper Wire, unannealed	60,000	——	——	18,000,000
Iron, cast	15,000	80,000	18,000	12,000,000
Iron Wire, annealed	60,000	——	——	15,000,000
Iron Wire, unannealed	80,000	——	——	25,000,000
Iron, wrought	48,000	46,000	40,000	27,000,000
Lead, cast	2,000	——	——	1,000,000
Steel Castings	70,000	70,000	60,000	30,000,000
Steel, structural	60,000	60,000	50,000	29,000,000
Steel Wire, annealed	80,000	——	——	29,000,000
Steel Wire, unannealed	120,000	——	——	30,000,000
Steel Wire, crucible	180,000	——	——	30,000,000
Steel Wire, plow	268,000	——	——	——
Steel Wire, susp. bridge	200,000	——	——	30,000,000
Steel Wire, piano	300,000	——	——	——
Tin, cast	3,500	6,000	——	4,000,000
Zinc, cast	5,000	20,000	——	13,000,000

Average Strength of Common Materials Other Than Metals		
Material	Compression	Tension
Bricks, best hard	12,000	400
Bricks, light red	1,000	40
Brickwork, common	1,000	50
Brickwork, best	2,000	300
Cement, Portland, one month old	2,000	400
Cement, Portland, one year old	3,000	500
Concrete, Portland	1,000	200
Concrete, Portland, one year old	2,000	400
Hemlock	4,000	6,000
Pine, short leaf yellow	6,000	9,000
Pine, Georgia	8,000	12,000
Pine, White	5,500	7,000
White Oak	7,000	10,000

Factors of Safety				
Material	Steady Load	Load Varying from Zero to Maximum in one Direction	Load Varying from Zero to Maximum in both Directions	Suddenly Varying Loads and Shocks
Cast Iron	6	10	15	20
Wrought Iron	4	6	8	12
Steel	5	6	8	12
Wood	8	10	15	20
Brick	15	20	25	30
Stone	15	20	25	30

Comparative Strength of Timber and Cast Iron

Table showing the transverse strength of timber and of cast iron one foot long and one inch square.

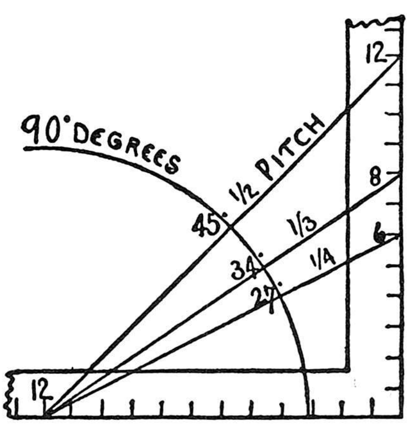
Material.	Breaking Weight, lbs.	Weight Borne with Safety, lbs.
Ash, seasoned	175	105
Chestnut, seasoned	170	115
Hickory, seasoned	270	200
White Oak, seasoned	240	196
White Pine, seasoned	135	95
Yellow Pine, seasoned	150	100
Iron (cast)	5,781	4,000

CARPENTER'S RULES

ROOF FRAMING

Definition of Terms.—The "gable" is the triangular end of a common double-roofed building. By the "pitch" of a roof is meant the relation which the height of the ridge above the level of the roof-plates bears to the span, or the distance between the studs on which the roof rests. Thus a roof that is one-half as high as the width of the building is "half-pitch," one that is one-fourth as high as the width is "quarter-pitch," etc.

The following illustration from Hodgson's "Practical Treatise on the Steel Square," not only shows the most common pitches, but also gives the degrees:



"Most carpenters," says Mr. Hodgson, "know that half-pitch is 45 degrees, yet few know third-pitch is nearly 34, and quarter-pitch about 27 degrees.

"A building 24 feet wide (as the rafters come to the center) has a 12-foot run and half-pitch, the rise would also be 12 feet, and the length of the rafter would be 17 feet (the diagonal of 12). Length, cuts, etc., could all be figured from the one illustration."

The Length of Rafters for the most common pitches can be found as follows from any given span:

If 1/4 pitch, multiply span by .559, or 7-12 nearly.
If 1/3 " " " " .6 , or 3-5 "
If 3/8 " " " " .625, or 5/8 "
If 1/2 " " " " .71 , or 7-10 "
If 5/8 " " " " .8 , or 4-5 "
If full " " " " 1.12 , or 1 1/8 "

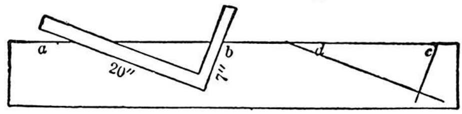
To lengths thus obtained must be added amount of projection of rafters at the eaves. Continued on next page

CARPENTER'S RULES

As rafters must be purchased of even lengths, a few inches more or less on their lengths will make a difference to the pitch so slight that it cannot be detected by the eye.

Example.—To determine the length of rafters for a roof constructed one-half pitch, with a span of 24 feet—24×.71=17.04; or, practically, just 17 feet. A projection of one foot for eaves makes the length to be purchased 18 feet.

How to Find Bevels and Length of Rafters

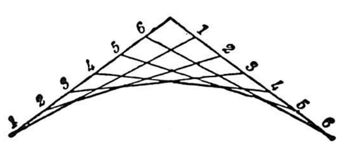


How to Find the Length and Bevels of Rafters.

1. **Bevels.**—Place your steel square on a board (say the building is 40 feet long), with the corner 20 inches from the edge of the board one way and 7 inches the other, and mark it as shown in the above figure. The angle at *c* will be the bevel of the upper end, and the angle at *d* at the lower end of the rafter.

2. **Length.**—From *a* to *b* on the outer edge of the board is the length of the rafter. The 20 inches shows the 20 feet, or half the width of the building; the 7 inches the 7 foot rise. The distance from *a* to *b*, on the edge of the board, is 21 inches, two-twelfths and one-quarter of a twelfth (always use a square with inches on one side divided into twelfths), therefore this rafter will be 21 feet and 2¼ inches long.

How to Determine Curves for Brick and Stone Arches



Measure width required and draw the figure above indicated. If the points in the figures are equal on both sides, the curve will be an exact part of a circle.

To Find the Area of a Gable End

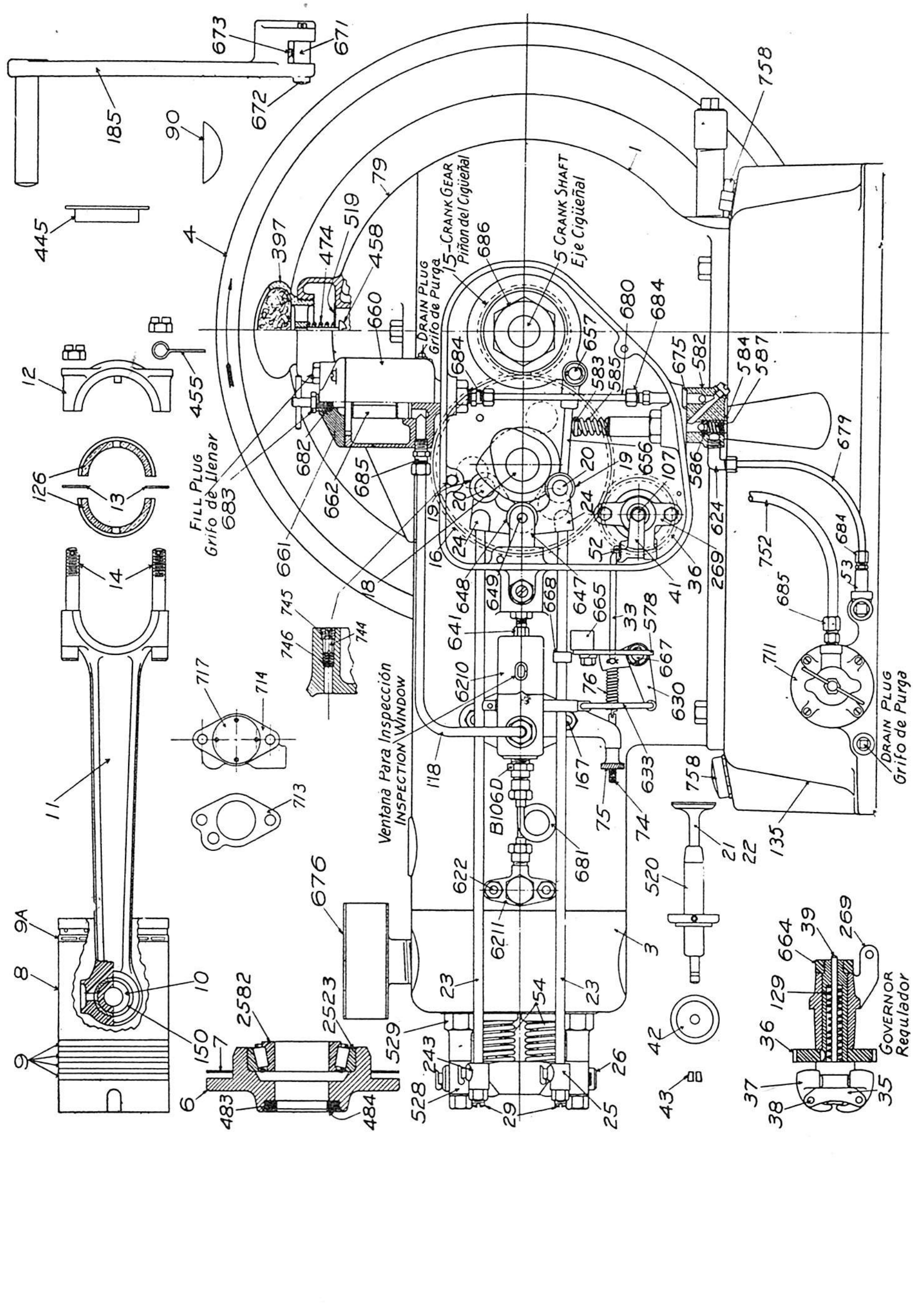
Multiply the width of the building by the height of the roof, and take one-half of the result. Or, if the roof is quarter-pitch, find the area by multiplying the width of the roof by ⅛ of itself.

Table for Finding the Contents of Square Tanks

A tank five feet by five feet holds	6 barrels.
A tank six feet by six feet holds	8½ "
A tank seven feet by seven feet holds	11½ "
A tank eight feet by eight feet holds	15¼ "
A tank nine feet by nine feet holds	19½ "
A tank ten feet by ten feet holds	23¾ "

The above table is for one foot of depth only.

To find the contents of a trough, measure its depth in feet and multiply it by the contents of one foot in depth.


15–CRANK GEAR
Piñon del Cigüeñal
5 CRANK SHAFT
Eje Cigüeñal
DRAIN PLUG
Grifo de Purga
FILL PLUG
Grifo de Llenar
Ventana Para Inspección
INSPECTION WINDOW
DRAIN PLUG
Grifo de Purga
GOVERNOR
Regulador

DIESEL ENGINE PARTS AS SHOWN ON ABOVE CHART

1	Clyinder and Base
3	Cylinder Head and Gasket
4	Fly-wheel
5	Crankshaft
6	Side Bearing Plate
7	Side Bearing Plate Shims
8	Piston
9	Piston Ring
9A	Oil Regulating Ring
10	Piston Pin
11	Connecting Rod Assembly (includes 11, 12, 13, 14, 126, 150, 455)
13	Crank Pin Bearing Shims
14	Connecting Rod Bolt, Nut and Cotter
15	Crank Gear
16	Camshaft Gear
18	Camshaft
19	Cam Roller and No. 20 Pin
21	Exhaust Valve—Silcrome Steel
22	Inlet Valve—S.A.E. Steel
23	Valve Push Rod
24	Valve Roller Rocker Assembly — Includes 19, 20
25	Exhaust Valve Rocker Assembly—Includes 29 and Nut
26	Valve Rocker Fulcrum Pin with Oiler and Cotter
*27	Valve Roller Rocker Pin
29	Valve Rocker Lever Adjusting Screw
33	Governor Link
35	Governor Hub
36	Governor Gear
37	Governor Weights and 38 Pins
38	Governor Weight Pins
39	Governor Center Pin
41	Governor Lever and 107 Screw
42	Valve Spring Washer
43	Valve Spring Washer Lock
52	Governor Lever Pin
53	Fuel Strainer
54	Inlet or Exhaust Valve Spring
74	Speed Changer Screw
75	Speed Changer Nut
76	Speed Changer Spring
79	Crankcase Cover
*86	Cylinder Head Gasket
90	Flywheel Key
*100	Cylinder Head Stud
*105	Piston Pin Lock Screw and Cotter Key
107	Governor Lever Screw
118	Fuel Line
126	Crank Pin Bearing
129	Governor Spring
135	Subbase and Fuel Tank
150	Piston Pin Bushing
185	Starting Crank Assembly
243	Inlet Valve Rocker Assembly
244	Valve Rocker Arm Roller and 245 Pin
269	Governor Bearing
*362	Cam Case Cover Assembly
397	Crankcase Filler Cap
*435	Subbase Gasket
445	Oil Slinger
*448	Crankcase Cover Gasket
*449	Camcase Cover Gasket
455	Oil Splasher Wire
458	Crankcase Filler Screw
*464	Gam Gear Key
*465	Crankshaft Gear Key
474	Crankcase Filler Spring
483	Chankshaft Felt
484	Crankshaft Felt Retaining Washer
500	Piston Assembly-Includes 8, 9A, 9, 10, 105
505	Governor Assembly—Includes 35, 36, 37, 38, 39, 41, 52, 107, 129, 269, 664
509	Cylinder Head Assembly—Includes 3, 21, 22, 42, 43, 54, 520
519	Crankcase Filler Breather Valve
520	Inlet and Exhaust Valve Stem Guides
528	Rocker Shaft Bracket
529	Cylinder Head Stud Nut
578	Compression Release Lever
582	Fuel Transfer Pump Assembly — Includes 582, 583, 584, 585, 586, 57
584	Relief Valve Plug
585	Fuel Transfer Pump Plunger Spring
586	Fuel Transfer Pump Relief Valve
587	Fuel Transfer Pump Relief Valve Spring
*615	Camshaft Bearing—Short
616	Camshaft Bearing—Long
622	Nozzle Holder, Stud
624	Fuel Line Elbow
630	Governor Bell Crank
633	Injection Pump Link
641	Tappet Adjusting Screw and Lock Nut
647	Injection Pump Tappet Assembly—Includes 647, 648, 649
648	Injection Pump Tappet Roller
649	Injection Pump Tappet Roller Pin
656	Fuel Transfer Pump Lift Lever Assembly
657	Fuel Transfer Pump Lift Lever Stud
*659	Camshaft Nut
660	Fuel Filter Assembly — Includes 660 661, 662, 663, 682, 683
661	Fuel Filter Cover
662	Fuel Filter Cartridge
*663	Fuel Filter Cover Gasket
664	Governor Hub Nut
665	Compression Release Lever Stud
667	Governor Bell Crank Fulcrum Pin
668	Valve Rod Collar
671	Starting Crank Pawl
672	Starting Crank Pawl Pin
673	Starting Crank Pawl Spring
674	Fuel Transfer Pump Gasket
*675	Fuel Transfer Pump Discharge Line Packing
676	Air Filter and Silencer
679	Fuel Line—Includes 624, 684 Connectors
680	Fuel Transfer Tube—Includes 684
681	Fuel Injector Line Complete
682	Filter Stem Packing
683	Filter Stem Packing Nut
684	Fuel Line Connector—Small
685	Fuel Line Connector—Large
686	Crankshaft Nut
710	Lubr. Oil Filter Cartridge
711	Lubr. Oil Filter Flange
712	Lubr. Oil Filter Flange Gasket
713	Lubr. Oil Circulating Pump Body Gasket
714	Lubr. Oil Pump Body
715	Lubr. Oil Pump Rotor
716	Lubr. Oil Pump Idler
717	Lubr. Oil Pump Head and Idler Pins Assembly
718	Lubr. Oil Pump Bushing
719	Lubr. Oil Pump Head Gasket
744	Lubr. Oil Circulating Pump Relief Valve
745	Lubr. Oil Circulating Pump Relief Valve Seat
746	Lubr. Oil Circulating Pump Relief Valve Spring
752	Filter Pump Suction Line — with Sleeves and 685 Nuts
757	Oil Pressure Gauge
758	Lubr. and Fuel Oil Level Gauge
2523	Roller Bearing Cup
2582	Roller Bearing Cone
6021	Lubr. Oil Pump Assembly—Includes 714, 715, 716, 717, 718, 719, 747 and 685
6023	Lubr. Oil Filter Assembly—Includes 710, 711, 685
6210	Fuel Injection Pump Assembly
6211	Nozzle Holder Assembly Less Nozzle
6212	Nozzle Assembly

Parts marked * are not illustrated.

THE PISTON RING

The pistons, which receive the force of the explosion and expansion and transmit the motion to the connecting rod and crank, are commonly made of soft gray cast iron, although some pistons of aluminum and also of an aluminum alloy called lynite are being used.

The aluminum and alloy pistons have the advantage of being light, and it is also claimed that they radiate heat much faster than cast iron. Being lighter than cast iron, the aluminum or alloy piston is easier to move up and down in the cylinder.

The expansion of these pistons is more than for cast iron and, consequently, a greater clearance must be provided when they are being fitted to the cylinders. The pistons are turned and ground so that they will be a few thousandths of an inch smaller in diameter than the cylinder in order that there will be a good sliding fit without undue friction. The pistons are made gas-tight by means of cast iron piston rings placed in grooves around the body of the piston. Ordinarily, three rings, placed in the piston above the wrist pin, are used. In some cases an oil groove is also cut in the piston below the rings to improve the lubrication between the piston and the cylinder walls.

Piston rings are of two general types, the concentric and eccentric; the concentric rings are of uniform thickness, while the eccentric rings are considerably thicker on the side opposite the opening. It is impossible with a concentric ring to get a uniform bearing pressure between ring and cylinder wall, but with an eccentric ring, this is accomplished. In addition to these types, of one-piece rings, numerous patented and two-piece rings have been devised so as to get the advantages both of the concentric and eccentric types.

The pistons used in automobile engines are of the trunk type, explosions taking place on one end only. The other end is open and allows for the movement of the connecting rod. The length of the piston is usually 1¼ times the diameter. The head of the piston is commonly made flat, although occasionally pistons with slightly concave or convex heads are used.

PISTON RING-GAP CLEARANCE

The average ring-gap clearance, or the distance between the end of a gap-cut ring, should be .0015" (1½-thousandths) to .002" for each inch in diameter of the cylinder. Some of the manufacturers advise .003" clearance for each inch diameter of the cylinder.

The following gap clearance table below can be followed:

2" to 3"	.006"
3" to 3½"	.007"
3½" to 4"	.008"
4" to 4½"	.009"

S. A. E. DEPTH AND WIDTH OF RING-GROOVE

Size of Piston	Depth of Groove	Width of Groove
2½"	.113"	.126"
3"	.127"	.188"
3½"	.142"	.188"
4"	.158"	.188"
4½"	.174"	.251"
5"	.190"	.251"
5½"	.207"	.314"
6"	.224"	.314"
6½"	.240"	.377"

THE CONSTRUCTION OF THE PISTON

The Construction of a Piston Used in a Gasoline Engine

It is a single acting, or trunk, kind. Made of Cast Iron, and turned to a good working fit in the cylinder. Near the upper end three or four grooves are cut entirely around its outer circumference, and in these grooves the packing rings are sprung. The displacement of the piston is the volume swept out by the piston. It equals area of piston multiplied by length of stroke. The govern length of a piston when designing one is, for verticle cylinder, piston length should not be less than its diameter; and for horizontal cylinder, piston length should be never less than one and one-third diameter.

The law that governs the velocity or speed of a piston in an explosive motor. The velocity of a piston must be considerably less than the rate of combustion of the explosive mixture, in order that the motor may produce power. The estimated speed limit, or piston velocity, is between 14 and 16 feet per second.

The right kind of material for the contact points of the vibrator of an induction coil is platinum.

Mechanical Adjustments

. . . *General Maintenance*—Besides the ***three important maintenance duties, Oiling, Cooling and Fueling,*** there are a number of simple mechanical adjustments the average operator should understand, and make as occasions arise to avoid serious delays. Many times it is desirable merely to recognize the need of them, and have the work done by an experienced mechanic, but even then some rules of procedure will save time and expense. This part of the book, therefore, treats of adjustments to:

Valves and Valve Timing. Governors.
Bearings. Accessories.

THE VALVE MECHANISM

. . . *Testing Valves*—To secure the best power and economy, and to avoid missing and overheating, the valves should always seat fully, and hold a charge so that the hand crank will bounce back or "rock" as the engine is turned over. If the engine fails to offer added resistance to the crank on the compression stroke, the leakage can generally be heard as a hiss. If it comes most distinctly through the carburetor, the intake valve is leaking; through the exhaust, the exhaust valve is leaking or if most distinctly through the breather, the leak is past the piston and rings. Leaks at the spark plugs and petcocks can be seen while the engine is running. If any of the valves leak, they should all be inspected and reground.

. . . *Removing Valves*—It is always necessary to remove the cylinder head to take the valves out, and if care is used, injury to the cylinder head gasket will be avoided and a new one ***will not be required.*** The head can generally be loosened by cranking the engine after the hold-down nuts have been removed.

. . . *Valve Tappets*—By examination of the individual engine the workman can determined whether it is easier to remove the tappets or merely screw down the adjusting screw to give clearance for valve grinding. Either way will afford suitable working conditions.

. . . *Valve Spring Retainers*—The end of each valve stem is fitted with a shallow steel cup that surrounds the end of the valve spring, and is held to the stem either by a small horse shoe lock, a pair of wedge blocks or a thread and locking pin. The locking device must be removed before the valve can be withdrawn, and it is advisable to stuff rags beneath the valve stems to prevent these small pieces from falling into the engine or dropping out and becoming lost. To release the lock from the recess in the spring retainer, it is only necessary to pry the retainer up against the spring pressure far enough to push the horse shoe to one side, or let the wedge blocks fall away from the valve stem; with the screw type retainer withdraw the pin from the valve stem, and unscrew the retainer nut.

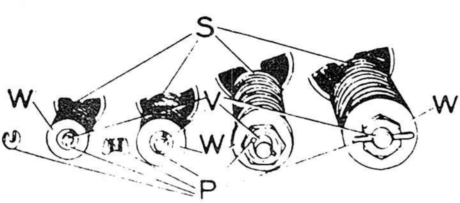


Fig. 1—***Standard Types of Valve Retainers and Locks***

P—Spring retainer lock. S—Valve spring. V—Lower end of valve stem. W—Spring retainer cup.

. . . *Examine Valve Seat*—Upon removing each valve, clean it thoroughly, and remove all carbon and burned oil. Carefully inspect the valve and valve seat for deep pits or shoulders that must be machined off before grinding begins. **Hy-Powr Engines have "shrouded" intake valves so that the valve is counter-sunk into the seat. This shoulder must not be removed. (See tabulated data.)**

. . . *Grinding Equipment*—To facilitate the grinding a light spring should be slipped on the valve stem which will serve to lift the valve off the seat when changing its grinding position. Any good commercial grinding compound may be used provided it is not too coarse.

. . . *Grinding the Valves*—Apply the grinding compound sparingly around the entire valve seat, slip the light lifting spring over the stem, lubricate the stem, and drop the valve into its original place in the cylinder block. The spring should just barely hold the valve off its seat. Exhaust valves can be identified from the intake valves by the number of grinding tool recesses in the top face. Exhaust valves have four recesses while intake valves have but two.

. . . ***Oscillating Motion*** — Place the grinding tool in the two holes in the head of the valve to be ground. Press down until the valve is seated. Turn the valve a quarter turn, first in one direction, then in the other. Do this three or four times. Release the pressure on the valve, and the little spring will lift it off its seat. Now turn the valve about 10 or 15 degrees to another position, and repeat the grinding. Do this until all

the compound is rubbed off the valve seat. Withdraw the valve, and put on some fresh compound. Repeat the grinding operation.

• • • *Don't Over-Do the Grinding* — Clean the valve and its seat occasionally to see how the grinding is progressing. When all pits and grooves have disappeared, place eight or ten equally spaced marks with a soft lead pencil on the cleaned face of the valve seat. Then drop the valve in place, give it a quarter turn, and remove it. A perfect seat will be indicated if every pencil mark shows where the valve has rubbed it. If any pencil marks are left untouched, continue the grinding. When the grinding is completed, oil the valve stem, ***clean all traces of the grinding compound*** from the valve chamber and cylinder walls in the combustion chamber, and re-assemble each valve in its proper port.

• • • *Don't Forget Tappet Clearance*— Refer to Tabulated Data, Figure for the proper valve tappet clearance. ***This must be right to avoid valve burning.***

• • • ***Never attempt to adjust the tappets without first releasing the lock nut.***

612 ***Do not use heavy wrenches on the valve tappet adjusting nuts as they are apt to break the tappet.***

VALVE TIMING

• • • *How to Check the Valve Timing*— Although the flywheel is marked to indicate the valve timing for No. 1 cylinder, and the gears are marked to insure that the camshaft is in correct relation to the crankshaft, it may be necessary on some occasion to check the valve timing. The easiest way with an L-head engine is by measuring the piston travel from top dead center at various valve positions. The valve-in-head engines must be checked by the marks on the flywheel and on the timing gears.

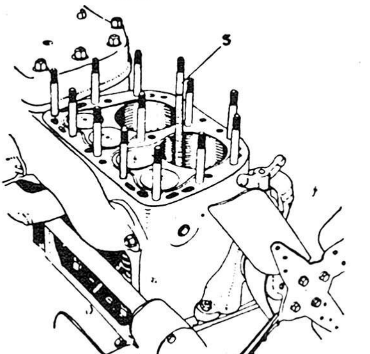


Fig. 2. —*Measuring for Dimension "A"*
S—Scale measuring from top of piston to top dead center position.

• • • *Remove Cylinder Head*—Before taking any measurements ***be sure*** the exhaust ***valve tappet clearance*** is as specified in the Tabulated Data, Figure otherwise the timing cannot be correctly set. Rotate the mushroom type tappets when checking the clearance to make sure there are no high spots. Now with the cylinder head off, measure the distance the piston of No. 1 cylinder ***has traveled down*** when the exhaust valve just starts to open. This distance corresponds to Dimension "A" in the Tabulated Data, Figure This can be measured directly with a steel scale "S" as shown in Figure 14. ***Don't forget it is the MOVEMENT that must be measured.***

• • • *Check Tappet Clearance*—Having checked the opening of the exhaust valve for No. 1 cylinder, it is unnecessary to check the relative setting of the camshaft and crankshaft for any other valves as the cams are all forged integral with the shaft, although the ***tappet clearance of each valve should be carefully checked and set.***

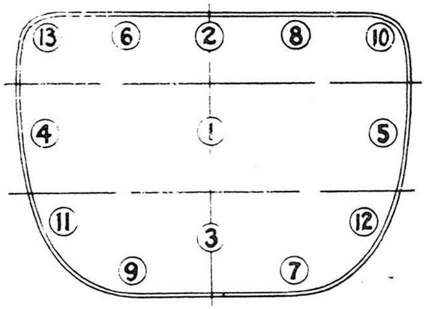


Fig. 3.—*Typical Cylinder Head Layout*
The order in which cylinder head nuts should be tightened is shown by consecutive numbering. Pull down snugly the first time. Then repeat drawing each nut tight. After the engine gets hot tighten a third time.

• • • *Replacing Cylinder Head*—There is a best way to replace cylinder heads that should always be followed to prevent trouble later. As shown in the typical case illustrated, the hold-down studs should be tightened in successive stages and in such order as will insure even pressure over the entire surface of the cylinder head and gasket. If the outside nuts are pulled up first instead of the center ones, the head will be cocked, and the gasket will not fit tight enough to prevent burning or blowing out between cylinders. Some Hy-Powr Engines have oil-seal washers on the hold-down studs which pass through the intake ports of the head. Be sure that these washers are replaced on the proper studs in good condition—otherwise an excess of lubricating oil will be drawn into the cylinders and wasted.

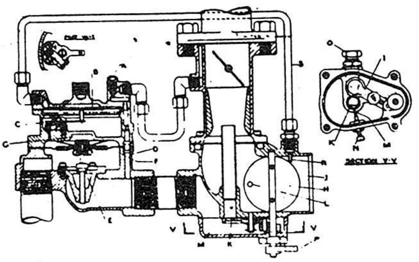


Figure 4—Ensign Gas Carburetor and Fuel Regulator

A—Idle fuel adjustment. B—Upper or pilot diaphragm. C—Pilot valve. D—Section passage from engine. E—Main fuel supply valve. F—Main diaphragm. G—Restricted passage. H—Air choke for starting. I—Gas shutter. J—Air intake. K—Gas passage. L—Air orifice in choke. M—Gas orifice used in choking. N—Adjustment for gas passage. O—Main fuel adjustment. P—Choke lever. R—Nozzle in atmosphere by-pass to regulator diaphragm. S—Atmosphere by-pass to regulator diaphragm.

BEARING ADJUSTMENT

• • • *Taking Up Bearings*—It is not advisable for any inexperienced person to attempt bearing adjustment. However, it is necessary for the operator or owner to know the symptoms that indicate the need, and to be able to tell the mechanic who does the work what clearances and tolerances are required.

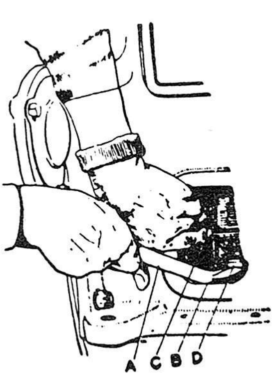


Figure 5— Testing Connecting Rod Bearings

A—Pry bar. B—Fulcrum point on case. C—Fingers overlap rod end and crank cheek. D—Connecting rod lower end.

• • • *Bearing Looseness*—In general, any bearing that is loose will cause an abnormal knock that increases with use. The heavier the thump, the greater the need for prompt attention. Call in the mechanic, have him locate the cause of the trouble, and remedy both the cause and the trouble itself.

• • • *Locating Loose Bearings*—A loose connecting rod bearing may be located by running the engine slowly, and short circuiting each spark plug in turn. If any connecting rod bearing is loose, the knock will disappear when that particular cylinder is cut out. A knock in a main bearing is harder to locate, and after all other possible causes of the knock have been investigated and eliminated, remove the oil pan or inspection plate, and try the adjustment of the main bearings.

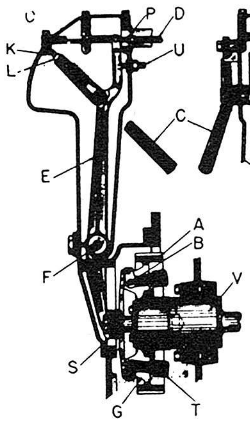
• • • *Inspecting Main Bearing Caps*—It is possible to make an inspection of the main crankshaft bearing caps one at a time without removing the crankshaft. If any trouble has been experienced it will be evident in the cap. If the bearings are loose, but otherwise in good condition, it is possible to take out shims enough to make up for the wear which has taken place. It is very important when doing this to take the same amount out of each of the bearings and each of the shims, otherwise the crankshaft will be thrown out of line, and even as little as a few thousandths of an inch will cause excessive friction in the bearings, wear, and loss of power. Do not remove so many thicknesses of shims that the caps pinch the shaft when the nuts are pulled as tight as possible.

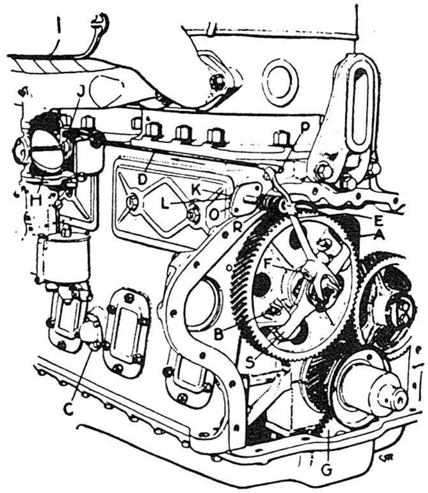
• • • *Bearing Clearances*—If it is necessary to replace the entire bearing in any case, the side clearances are important. Connecting rods should have side clearance as shown in Tabulated Data, Figure ; Dimension "B." Main crankshaft side clearances are also shown in the Data. Dimension "C" is the thrust bearing side clearance, while Dimension "D" is the side clearance for all other crankshaft bearings.

THE GOVERNOR MECHANISM

• • • *A Protective Device*—The governor built into Waukesha Engines is designed for each particular engine to do two main things 1—to prevent damage from overspeeding as mentioned in the "CAUTION" following the guarantee (see page 118 —to automatically maintain constant speeds under varying loads while driving industrial machinery. ***As the life of any machine falls off rapidly when it is speeded up beyond safe limits,*** the governor should be kept in operation at all times to protect the engine against damage and abuse.

• • • *Governor Adjusting*—The governor is adjusted for the correct speed at the factory, and ***should not be changed*** to a higher speed ***without consulting the Company.*** The general rules given here apply only in those cases where it may be necessary to re-assemble the governor after the manifolds have been taken down or other work





Above — Governor used on Model 6-LRO.
Right — Governors used on Models HS, HL, WS, WL, WK, WOK, 6-MS, 6-ML, 6-MK, 6-MKR, 6-MZ, 6-MZR, 6-SRS, 6-SRL, 6-SRLR, 6-SRK, 6-SRKR, 6-RB, 6-RBR, 6-EL, 6-EK, 6-NK, 6-LS, 6-LK.

***Figure 6**— Typical Large Engine Governor Mechanisms.*
A—Camshaft gear to which governor weights are attached by pins, B. C—Speed adjusting lever. D—Governor operating rod. E—Governor lever. F—Governor lever pin hole. G—Governor weight support. H—Governor valve. J—Governor valve shaft mounted on ball bearings. K—Speed adjusting screw. L—Adjustment locking nut. O—Governor spring housing. P—Ball joint. R—Governor spring. S—Governor shift plate. T—Governor weights. U—Stop screw to prevent surging. V—Drive shaft.

done which incidentally involves the governor mechanism.

• • • *Governor Types*—In general principle, all Waukesha governors are alike, and in all but two or three engines, the general arrangement and location of the parts are the same The general scheme is shown in *Figure 6*— which applies to the larger sizes, while Figures 7 and 8 show the special arrangement used for the small fours and sixes as indicated by the title, and Figure 9 the type used on valve-in-head engines. Each of these is automatically lubricated by the engine oiling system.

• • • *Operation of Governor* — The operation of the Waukesha governor is as follows: Two weights in the gear chamber attached to gear, A, Figure 6 are held by and swivel around two pins, B. These weights fly out when the engine speeds up, moving the governor shifter, S, outward. This action presses a ball bearing thrust at the center of S, outward. This moves lever, E, Figure 6 This lever, E, swivels on pin, F,

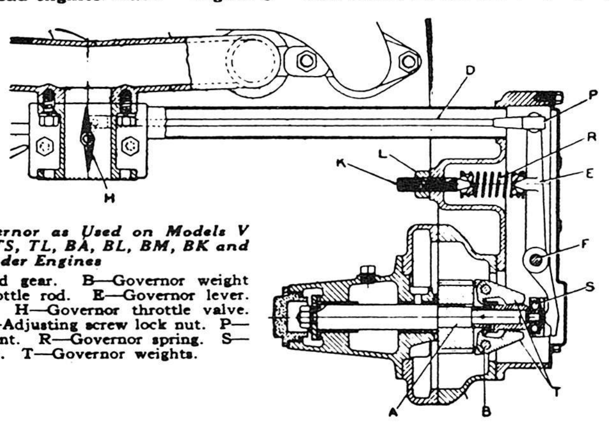
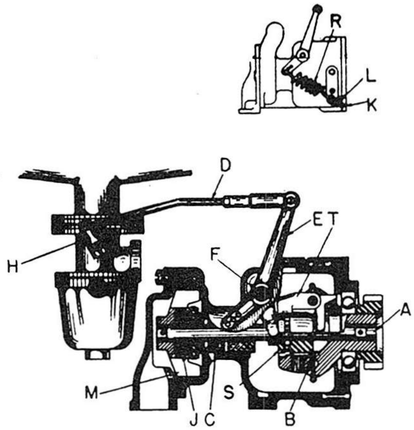
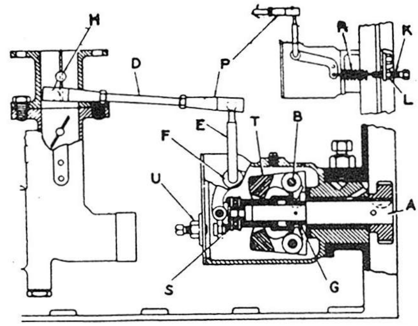


***Figure 7**— Diagram of Governor as Used on Models V and VK Four-Cylinder, and TS, TL, BA, BL, BM, BK and BZ Six-Cylinder Engines*

A—Governor drive shaft and gear. B—Governor weight hinge pins. D—Governor throttle rod. E—Governor lever. F—Governor lever hinge pin. H—Governor throttle valve. K—Speed adjusting screw. L—Adjusting screw lock nut. P—Throttle rod adjustable ball joint. R—Governor spring. S—Governor ball thrust shift plate. T—Governor weights.





Above — Governor as used on Models FCS, FS, FL, FC, XAH, XAK.

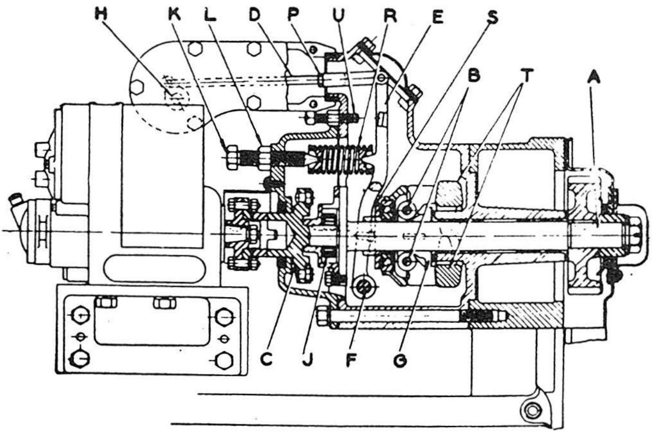
Left — Combination Governor and Water Pump used on Model ICK.

Figure 8—Diagrams of Governors Used on Small Four-Cylinder Engines

A—Governor drive shaft and gear. B—Governor weight hinge pins. C—Water pump seal—external. D—Governor throttle rod. E—Governor lever. F—Governor lever hinge pin. G—Governor weight support keyed to drive shaft. H—Governor throttle valve. J—Water pump seal—internal. K—Speed adjusting screw. L—Adjusting screw lock nut. M—Water pump impeller. P—Throttle rod adjustable ball joint. R—Governor spring. S—Governor ball thrust shift plate. T—Governor weights. U—Stop screw to prevent surging.

Figure 9 –Diagram of Governor for Overhead Valve Engines

A — Governor drive shaft and gear. B—Governor weight hinge pins. C — Magneto impulse coupling. D—Governor throttle rod. E—Governor lever. F — Governor lever hinge pin. G—Governor weight support keyed to drive shaft. H — Governor throttle valve rod. J—Magneto impulse coupling spring. K — Speed adjusting screw. L—Adjusting screw lock nut. P—Throttle rod adjustable ball joint. R—Governor spring. S—Governor ball thrust shift plate. T — Governor weights. U — Stop screw to prevent surging.



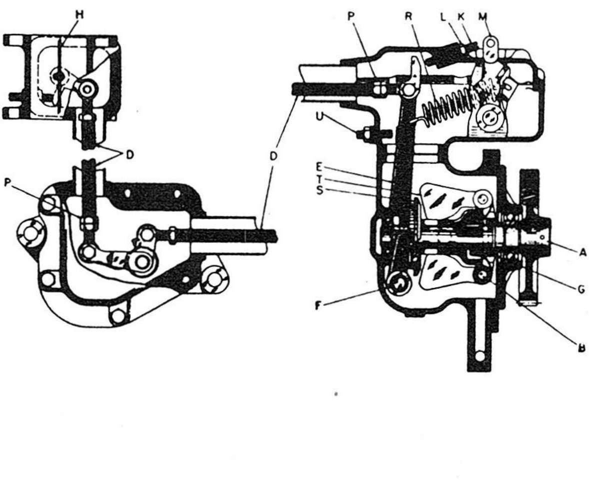


Figure 10— Diagram of Close Regulating Type Governor Used on Models 6-GAL and 6-GAK

A—Governor drive shaft and gear. B—Governor weight hinge pins. D—Governor throttle rod. E—Governor lever. F—Governor lever hinge pin. G—Governor weight support keyed to drive shaft. H—Governor throttle valve. K—Speed adjusting screw. L—Adjusting screw lock nut. M—Speed adjusting lever. P—Throttle rod adjustable ball joint. R—Governor spring. S—Governor ball thrust shift plate. T—Governor weights.

which is held in the gear cover. The movement of E, causes a movement of the rod, D, which closes the butterfly valve, H, and throttles the engine independently of the carburetor throttle.

• • • *Governor Accelerator*—In operating some industrial machinery there are periods in the operating cycle which demand an excess of power beyond the routine requirements—raising the loaded skip of a paving mixer, and starting a heavy hoist load are common examples—which can be met by properly connecting the Waukesha governor accelerator. Its action is fully diagrammed in *Figure 11*, and its use should be restricted to such service as just described. *It should not be used* for operating the engine *continuously* at its maximum accelerated speed.

• • • *Re-Setting the Governor*—As previously stated, governor adjustments should only be necessary if the governor or parts included in its assembly have been taken down for other work such as manifold gasket replacement, timing gear adjustment or gear cover gasket renewal. If any of this work deranges the governor parts be sure that it is re-assembled as it was originally. Make sure that the ball joint lock nut at P, Figure 6, is tight, and that the governor throttle valve is assembled right side up as indicated by the raised letters cast in the

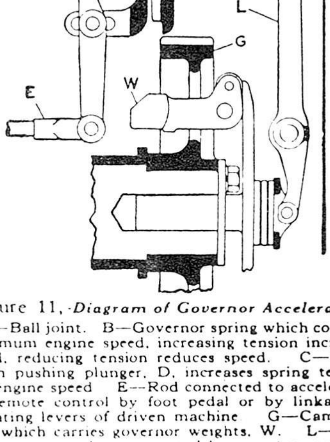


Figure 11, *Diagram of Governor Accelerator*

A—Ball joint. B—Governor spring which controls maximum engine speed, increasing tension increases speed, reducing tension reduces speed. C—Lever which pushing plunger, D, increases spring tension and engine speed E—Rod connected to accelerator for remote control by foot pedal or by linkage to operating levers of driven machine G—Camshaft gear which carries governor weights, W. L—Governor operating lever actuated by governor weights. R—Governor valve operating rod.

edge of the butterfly itself. If all of these points have been carefully followed, the governor should operate exactly as before, provided the tension of the spring, R, or the length of the rod, D, has not been changed. To secure the best regulation, make sure that the length of the rod, D, is adjusted so that the throttle, H, stands a trifle towards the closing position when the engine is stopped. Variation from the speed shown in the Tabulated Data, Figure can be corrected by the screw, K. Turning it clockwise increases the maximum speed, counter-clockwise, decreases the speed.

SPECIAL EQUIPMENT

• • • *Auxiliary Accessories*—There are many auxiliary accessories that are applied to Waukesha Engines from time to time, each one usually meeting the special need of some individual client. The principal items include air compressors for air brakes, large capacity electric generators and special cylinder lubricating systems.

AIR BRAKE COMPRESSORS

• • • *Air Compressors*—There are three general types of air compressor mounting, each one designed with automatic lubrication system. The forward chain drive mounting and its typical application to the engine is shown in *Figure 12* In this type, the silent chain is entirely enclosed, and receives oil from the engine oiling system. Do not use grease. The chain slack is adjusted either by an idler as shown in the diagram sketch, or by shims being placed beneath the compressor itself. The belt drive forward mounting is too simple to require description. The care of the compressor is covered by the air compressor manufacturer's instruction book. NEVER CHANGE the size of the oil line feed, to do so will unbalance the engine oil distribution.

• • • *Rear Mounted Compressor*—A special bracket replacing the magneto bracket is used for the rear mounting, therefore, battery ignition must be used. As in the case of the front mounted compressor, the lubrication is entirely automatic from the engine system, and does not require any attention. Do not put grease in the gear case. Adjustment of the chain should be made by shims under the compressor base.

ELECTRIC GENERATORS

• • • *Generator Selection*—Occasionally generators for storage battery charging and auxiliary lights are required with capacities from 300 to 800 watts. If, for any reason, this equipment is not furnished by the Waukesha Motor Company and with specific recommendations, it is important that care be exercised in its selection. Make sure that the generator is of the proper size, that it is equipped with a voltage regulator, and that

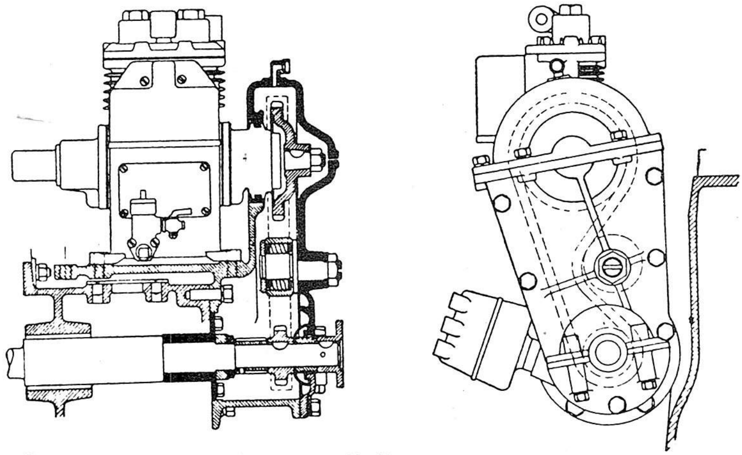


Figure 12—*Diagram of Chain Drive Air Compressor Mounting of Early Design; Later Designs Have No Idler.*

the charging rate is adjusted to meet the electrical load. This will prevent damage to the storage battery.

• • • *Generator Care*—Specific instructions for the care of generator are included in the accessory makers' directions furnished with these units. When the generator is bolted by a flange to the timing gear housing, it is important, in mounting, to see that sufficient back lash be allowed between the generator and driving gears to avoid over-heating the generator bearing.

• • • *Generator Noises*—If a rattle or thump is located in the generator at low engine speeds, it can generally be traced to too much back lash in the gears or excessive end play in the generator. Correct the back lash in the gears by loosening the upper attaching screws, and crowding the generator slightly toward the crankcase. This can be done most conveniently if the cap screws are only freed enough to move the generator by light blows from a rawhide or wooden mallet. When proper running conditions are secured, tighten the cap screws. If it is end play, it is controlled in different ways in different machines, and the trouble should be located, and remedied by the nearest service representative of the electrical equipment manufacturer.

SPECIAL LUBRICATION

• • • *For Special Industrial Service*—Extra precautions are necessary to insure ample lubrication of industrial engines that must be started after long periods of rest, or after standing in a cold place. They should be filled with fresh warm oil, and run idle for the first few minutes to permit the oiling system to fill, and insure oil reaching all parts of the engine. It is good practice where industrial equipment stands out of doors overnight in cold weather, to drain the oil from the crankcase each evening and keep it in a warm place, replacing it in the crankcase the following morning. ***Do not put it near a stove or open fire.***

• • • *Fire Engine Equipment*—Fire engine equipment requires special care to avoid serious damage when it is new. Until the engine has been thoroughly limbered by at least 300 hours of service, ***lubricating oil must be added to the fuel***—one pint of oil to each five gallons of gasoline. If the equipment is kept in a station where the temperature is below 50, unless the apparatus is in frequent use, a lighter oil should be used than the standard recommendation given in the Tabulated Data, Figure Specifications for this service call for a ***viscosity of 65 to 70 Saybolt at 210 degrees F., not over 600 viscosity at 100 degrees F.*** with a minimum flash point of 420 degrees F. Beside using a lighter oil, the oil supply should be checked frequently, and maintained at top level. When checking the oil supply if the drop from the bayonet gauge is thin and fast, it indicates poor lubricating qualities, and the oil should be changed.

. . . *Electric Oil Heaters*—The most satisfactory arrangement to insure prompt response of the lubricating system is the use of a small electric heater attached to the oil pan sump. This will serve to keep the oil at a proper consistency in the coldest weather, and will also avoid the accumulation of water and gasoline in the sump. Not over 100 to 150 watts are needed. Our Engineering Department will provide suitable sketches on request, showing a permanent attachment of this kind.

DUPLEX OILING

(*Obsolete Equipment*)

. . . *The Duplex System an "Extra"*—In special cases, the added precaution of directly oiling the cylinder walls and pistons is recommended, and for this purpose the Madison-Kipp Duplex Oiling System was devised. It is auxiliary to and not a substitute for the standard pressure circulating system. It provides a positive delivery of fresh oil in a metered quantity at regular intervals to each piston and cylinder, as soon as the engine starts instead of depending entirely upon crankcase mist for this duty.

. . . *Simple Equipment* — The extra equipment is securely built into the engine, and consists of an outside oil reservoir with a glass level gauge, and a tube which connects it to a fitting on the outside of the crankcase. The oil in this tank is led to a valveless plunger pump which receives a predetermined quantity of oil, and forces it through a distributing valve to each cylinder in turn. This pump is incorporated in the drive of the main oil pump, and is driven by a worm as shown in Figure 13

. . . *Keeping the System Clean*—Owing to the small quantities of oil which are used, even with the relatively large oil tubes employed, particles of foreign matter and sludge sometimes collect and stop the system. It has been found that this collects most frequently in the tube leading from the supply tank to the crankcase, and that by blowing out this tube, the system will be restored to full operation. ***Do not*** attempt any ***adjustment*** of the Duplex oil feed ***without*** first clearing this outside delivery pipe.

. . . *Adjustment of Oil Feed*—An adjusting screw is provided at, A, Figure 13 To increase the rate of oil feed, turn the screw counter-clockwise; to decrease the rate of feed, turn it clockwise. This screw may be reached by removing a plug in the side of the oil pan. It is unnecessary to remove the pan for any of the oiling system adjustments. A correct adjustment will add enough oil through the duplex system to balance the normal loss in the circulating system—usually about 11 drops per cylinder

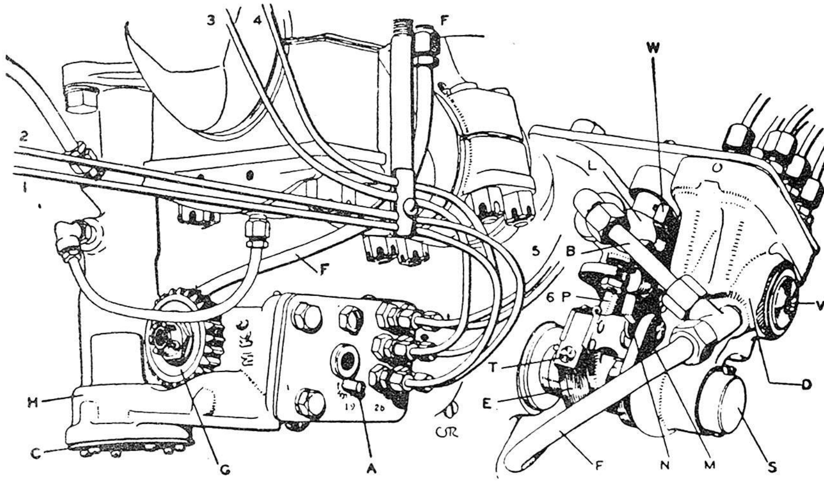


Figure 13— Details of "Duplex" Lubricating Pump

"Fresh oil" leads to their respective cylinders are indicated by the number of the cylinder, i. e., 1-2-3-4-5-6. A—Adjustment screw for regulating "fresh oil" pump. B—Cross over connection from feed line, F, to "fresh oil" pump cylinder, L. C—Cover over oil pump gears. G—Worm gear which drives "fresh oil" auxiliary pump. H—Housing for main oil pump. N—Pin on arm, M, which engages, W, and turns it one notch for each complete revolution of the shaft, S. P—"Fresh oil" pump piston. S—Eccentric shaft driven by worm wheel, G. T—Universal connection on end of piston and connected to driving eccentric, E. V—Rotary distributor valve which directs each shot of the plunger pump to the right cylinder—each cylinder in sequence. W—Distributor valve slow motion gear.

per minute—so that between crankcase draining periods all fresh oil is added to the engine through the duplex system. To check the delivery of oil to each cylinder, the small copper tube loop connecting the cylinder with the crankcase may be removed. Watch the oil level carefully, and if it is found to be increasing, reduce the duplex feed rate. If the level is falling, increase the duplex feed rate. Be sure that the oil is not thinning from an over-rich carburetor mixture.

· · · *Top Cylinder Oiling*—When removable sleeve cylinders are used, the Madison-Kipp Duplex System is replaced with the Jay Vacuum Operated "Motop" Oiler. This system is entirely automatic and equipped with a sight gauge, its operation is constantly in view. Follow the manufacturer's instructions accompanying the device if adjustments are needed. Always use the best grade of light oil as recommended by the maker.

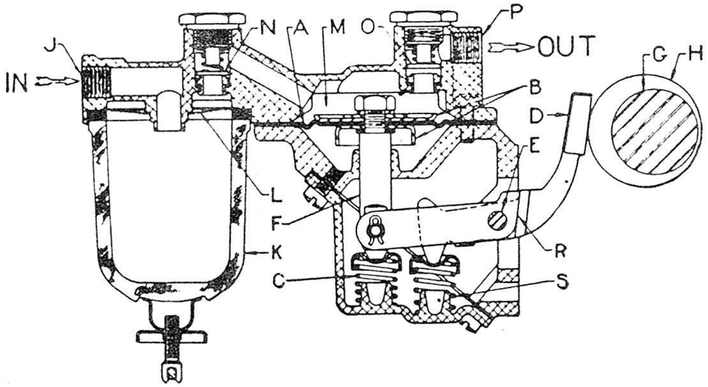


Figure 14—Operation Diagram of Typical Reciprocating Fuel Pump

The eccentric, H, on revolving shaft, G, moves the lever, D, back and forth, and pulls diaphragm plunger, F, up and down against the spring, C. This draws fuel by vacuum into the upper chamber, M, through the check valve, N, from the supply line connected at J. When the diaphragm, A, moves up, the fuel is forced through the valve, O, and opening, P, to the carburetor. When the carburetor float chamber is full and the float holds the needle valve closed, the back pressure on the diaphragm holds it down, the motion of the lever, D, is absorbed by the joint, R, instead of the diaphragm plunger, F.

hand, the general principles of adjusting all carburetors here outlined will give fair to good results.

CARBURETOR ADJUSTING

· · · *Low Speed Adjustment*—In making carburetor adjustments the usual object is to secure the best pulling power possible. This does not necessarily mean the highest or lowest speed or best economy of the engine. When adjusting the carburetor, first set the spark in the position found most favorable for pulling, and leave it there while making all adjustments. The idling adjustment should be made first, with the gas control nearly closed. If the engine loads up or seems logy, it is an indication that the mixture is too rich. If the engine slows down and pops in the carburetor, the mixture is too lean.. Adjustment should be made accordingly—by the low speed adjustment only.

High Speed Adjustment—In making the high speed adjustment, do not change the spark control, but set the gas throttle about one-fourth open, that is, one-fourth away from the closed position. The high speed adjustment should then be turned either right or left, depending on which way it gives the desired effect, until the engine runs smoothly. If possible make this adjustment with the ***engine under load,*** so ***that*** if a ***governor*** is used, it ***will not be affecting the adjustment.*** When the desired results are thus obtained, retard the throttle control, and allow the engine to idle for at least one minute. When this is done, quickly open the throttle about one-third and then quickly close it. If the mixture is too lean, it will pop back through the carburetor, indicating that the high speed fuel feed adjustment must be opened slightly, or if an air adjustment is used, the air flow slightly decreased. If the mixture is too rich, a popping noise will come from the muffler or exhaust outlet, and the high speed fuel feed adjustment should be closed slightly or the air adjustment opened to the desired position. A little experience and careful attention will make possible all carburetor adjustments which may be necessary, but if the engine is working well, ***don't experiment.*** The best pulling power will be obtained with a mixture slightly richer than the leanest mixture that will give smooth running.

TABULATED DATA

FOUR-CYLINDER ENGINES

ENGINE MODEL	FCS-FS	FL	FK-FC	XA	XAH	XAK	V	VK	VIS
Bore	2¾	3	3¼	3½	3⅝	3¾	4	4¼	4⅛
Stroke	4	4	4	4½	4½	4¾	5	5	5¼
Displacement, cu. in.	95	113	133	173	186	210	251	284	281
N.A.C.C. hp. rating (actual hp. is higher)	12.1	14.4	16.9	19.6	21.0	22.4	25.6	28.9	27.2
Oil capacity, qts., standard automotive type oil pan	4	4	4	4	4	4	7	7	10
Oil capacity, qts., flat base stationary type	8	8	8	9	9	9	11	11	12
Oil pressure, lbs. at 1000 rpm, hot	15	15	15	15	15	15	20	20	25
**Oil Specifications — Saybolt Viscosity @ 210° F.	65–75	65–75	65–75	65–75	65–75	65–75	65–75	65–75	65–75
**Oil Specifications — Kinematic viscosity @ 210° F., poises	.11-.13	.11-.13	.11-.13	.11-.13	.11-.13	.11-.13	.11-.13	.11-.13	.11-.13
**Oil Specifications — S.A.E. No	40	40	40	40	40	40	40	40	40
Water capacity, Industrial units, gals.	5	5	5	5½	5½	5½	9½	9½	12
Permissible Governed Speeds — Continuous, full load	1800	1800	1800	1500	1500	1500	1400	1400	1200
Permissible Governed Speeds — Intermittent, part load	2600	2600	2600	2200	2200	2200	2000	2000	1500
Valve tappet Setting, cold — Intake, inches	.005-	.005-	.005-	.004-	.004-	.004-	.005-	.005-	.014-
	.007	.007	.007	.005	.005†	.005	.006	.006	.016
Valve tappet Setting, cold — Exhaust, inches	.009-	.009-	.009-	.006-	.006-	.006-	.008-	.010-	.016-
	.011	.011	.011	.008	.008†	.008	.010	.012	.018
Firing Order	1-3-4-2	1-3-4-2	1-3-4-2	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3
Spark advance, maximum, flywheel, degrees	25°	18°	19°	29°	28°	30°	29°	31°	43°
Dimension "A" (See paragraph 614)	3 9/16	3 9/16	3 9/16	4 1/16	4 1/8	4 5/16	4 11/32	4 11/32	
Dimension "B" (See paragraph 621)	.004-	.004-	.004-	.005-	.005-	.005-	.005-	.005-	.010-
	.007	.007	.007	.010	.010	.010	.010	.010	.015
Dimension "C" (See paragraph 621)	.005-	.005-	.005-	.003-	.003-	.003-	.003-	.003-	.003-
	.009	.009	.009	.005	.005	.005	.005	.005	.005
Dimension "D" (See paragraph 621)	.030-	.030-	.030-	.015-	.015-	.015-	.015-	.015-	.060-
	.060	.060	.060	.025	.025	.025	.025	.025	.090

ENGINE MODEL	VIL	VIK	CSR	CR	DR	DKR	ER	CHS	CHK
Bore	4⅜	4½	4¼	4⅜	4½	4¾	5	4¾	5⅛
Stroke	5¼	5¼	5¾	5¾	6¼	6¼	6¼	6¼	6¼
Displacement, cu. in.	316	334	326	346	398	443	491	443	516
N.A.C.C. hp. rating (actual hp. is higher)	30.7	32.2	28.9	30.7	32.5	36.1	40.0	36.1	42.0
Oil capacity, qts., standard automotive type oil pan	10	10	8	8	9	9	10	15	15
Oil capacity, qts., flat base stationary type	12	12						14	14
Oil pressure, lbs. at 1000 rpm, hot	25	25	12	12	20	20	20	25	25
**Oil Specifications — Saybolt Viscosity @ 210° F.	65–75	65–75	65–75	65–75	65–75	65–75	75–105	75–105	75–105
**Oil Specifications — Kinematic viscosity @ 210° F., poises	.11-.13	.11-.13	.11-.13	.11-.13	.11-.13	.11-.13	.13-.20	.13-.20	.13-.20
**Oil Specifications — S.A.E. No	40	40	40	40	40	40	50	50	50
Water capacity, Industrial units, gals.	12	12	15	15	15	15	15	16	16
Permissible Governed Speeds — Continuous, full load	1200	1200	1200	1200	1100	1100	1050	1050	1050
Permissible Governed Speeds — Intermittent, part load	1500	1500	1500	1500	1400	1400	1200	1200	1200
Valve tappet Setting, cold — Intake, inches	.014-	.014-	.008-	.006-	.006-	.006-	.006-	.012-	.012-
	.016	.016	.010	.008	.008	.008	.008	.014	.014
Valve tappet Setting, cold — Exhaust, inches	.016-	.016-	.012-	.012-	.012-	.012-	.012-	.014-	.014-
	.018	.018	.015	.015	.015	.015	.015	.016	.016
Firing Order	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3
Spark advance, maximum, flywheel, degrees	45°	27°	25°	25°	24°	24°	23°	30°	43°
Dimension "A" (See paragraph 614)			5 5/32	5 5/32	5 21/32	5 21/32	5⅝	...	
Dimension "B" (See paragraph 621)	.010-	.010-	.010-	.010-	.010-	.010-	.010-	.006-	.006-
	.015	.015	.015	.015	.015	.015	.015	.012	.012
Dimension "C" (See paragraph 621)	.003-	.003-	.003-	.003-	.003-	.003-	.003-	.003-	.003-
	.005	.005	.005	.005	.005	.005	.005	.005	.005
Dimension "D" (See paragraph 621)	.060-	.060-	.030-	.030-	.030-	.030-	.030-	.060-	.060-
	.090	.090	.060	.060	.060	.060	.060	.090	.090

ENGINE MODEL	HS	HL	JI	JK	JZ	WS	WL	WK	WOK
Bore	5½	6	6	6½	6¾	5¾	6¼	6¾	7½
Stroke	6½	6½	7	7	7	8	8	8	8
Displacement, cu. in.	618	735	792	929	1002	831	982	1145	1414
N.A.C.C. hp. rating (actual hp. is higher)	48.5	57.6	57.6	67.7	72.9	53.0	62.5	72.9	90.0
Oil capacity, qts., standard automotive type oil pan	13	13	14	14	14	15	15	15	16
Oil capacity, qts., flat base stationary type	20	20	20	20	20	20	20	20	20
Oil pressure, lbs. at 1000 rpm, hot	30	30	25	25	25	25	25	25	25
**Oil Specifications — Saybolt Viscosity @ 210° F.	75–105	75–105	75–105	75–105	75–105	75–105	75–105	75–105	75–105
**Oil Specifications — Kinematic viscosity @ 210° F., poises	.13-.20	.13-.20	.13-.20	.13-.20	.13-.20	.13-.20	.13-.20	.13-.20	.13-.20
**Oil Specifications — S.A.E. No	50	50	50	50	50	50	50	50	50
Water capacity, Industrial units, gals.	17½	17½	26	26	28	28	28	28	36
Permissible Governed Speeds — Continuous, full load	1050	1050	950	950	950	950	950	950	900
Permissible Governed Speeds — Intermittent, part load	1200	1200	1050	1050	1050	1050	1050	1050	1000
Valve tappet Setting, cold — Intake, inches	.006-	.006-	.008-	.008-	.008-	.008-	.008-	.008-	.014-
	.008	.008	.010	.010	.010	.010	.010	.010	.016
Valve tappet Setting, cold — Exhaust, inches	.012-	.012-	.015-	.015-	.015-	.015-	.015-	.015-	.024-
	.015	.015	.017	.017	.017	.017	.017	.017	.026
Firing Order	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3	1-2-4-3
Spark advance, maximum, flywheel, degrees	21°	27°	23°	25°	25°	21°	23°	24°	32°
Dimension "A" (See paragraph 614)	5 13/16	5 13/16	6 7/32	6 7/32	6 7/32	7 3/32	7 3/32	7 3/32	
Dimension "B" (See paragraph 621)	.006-	.006-	.010-	.010-	.010-	.010-	.010-	.010-	.010-
	.012	.012	.015	.015	.015	.015	.015	.015	.015
Dimension "C" (See paragraph 621)	.003-	.003-	.006-	.006-	.006-	.006-	.006-	.006-	.006-
	.005	.005	.008	.008	.008	.008	.008	.008	.008
Dimension "D" (See paragraph 621)	.030-	.030-	.030-	.030-	.030-	.030-	.030-	.030-	.030-
	.060	.060	.060	.060	.060	.060	.060	.060	.060

SIX-CYLINDER ENGINES

ENGINE MODEL	6ZKA	6BA	6BL	6BM	6BK	6BZ	6MS	6ML	6MK
Bore	3 3/8	3 3/8	3 1/2	3 5/8	3 3/4	4	3 3/4	4	4 1/8
Stroke	4 1/8	4 1/4	4 1/4	4 1/4	4 1/4	4 1/4	4 3/4	4 3/4	4 3/4
Displacement, cu. in.	221	228	245	263	282	320	315	358	381
N.A.C.C. hp. rating (actual hp. is higher)	27.3	27.3	29.4	31.5	33.8	38.4	33.8	38.4	41.0
Oil cap., qts., std. auto type oil pan	6	8		8			8	8	8
Oil capacity, qts., flat base stationary type	......	12		12			......	......	......
Oil pressure, lbs. at 1500 rpm, hot	40	40		40			40	40	40
**Oil Specifications: Saybolt Viscosity @ 210° F.	65–75	65–75		65–75			75–105	75–105	75–105
**Oil Specifications: Kine. visc. @ 210° F., poises	.11-.13	.11-.13		.11-.13			.13-.20	.13–.20	.13-.20
**Oil Specifications: S.A.E. No.	40	40		40			50	50	50
Water capacity, Industrial units, gals.	9 1/2	9 1/2		9 1/2			10	10	10
Permissible Governed Speeds: Continuous, full load	1800	2000		2000			1600	1600	1600
Permissible Governed Speeds: Intermittent, part load	2500	2800		2800			2200	2200	2200
Valve tappet Setting, cold: Intake, inches	.008-.010	010-.012		.010-.012			008-010	.008-.010	.008-.010
Valve tappet Setting, cold: Exhaust, inches	.012-.014	.014-.016		.014-.016			014-016	.014-.016	.014-.016
Firing Order	1-5-3-6-2-4	1-5-3-6-2-4		1-5-3-6-2-4			1-5-3-6-2-4	1-5-3-6-2-4	1-5-3-6-2-4
Spark advance, maximum, flywheel, deg.	25°	30°		34°			25°	24°	25°
Dimension "A" (See paragraph 614)	4 1/4	3 5/8		3 5/8			4 1/4	4 1/4	4 1/4
Dimension "B" (See paragraph 621)	.005-.010	.005-.010		.005-.010			.005-.010	.005-.010	.005-.010
Dimension "C" (See paragraph 621)	.003-.005	.003-.005		.003-.005			003-.005	.003-.005	.003-.005
Dimension "D" (See paragraph 621)	.010-.045	.060-.090		.060-.090			.010-.045	.010-.045	.010-.045

ENGINE MODEL	6MZ	6SRS	6SRL	6SRK	6DHS	6DHK
Bore	4 1/4	4 1/8	4 3/8	4 5/8	4 1/2	5
Stroke	4 3/4	5 1/8	5 1/8	5 1/8	5 1/2	5 1/2
Displacement, cu. in.	404	411	462	517	525	648
N.A.C.C. hp. rating (actual hp. is higher)	42.5	41.0	46.0	51.3	48.6	60.0
Oil cap., qts., std. auto type oil pan	8	10	10	10	14	14
Oil capacity, qts., flat base stationary type	......	......	......	13 1/2	......	......
Oil pressure, lbs at 1500 rpm, hot	40	40	40	40	50	50
**Oil Specifications: Saybolt Viscosity @ 210° F.	75–105	75–105	75–105	75–105	75–105	75–105
**Oil Specifications: Kine. visc. @ 210° F., poises	.13-.20	.13-.20	.13-.20	.13-.20	.13-.20	.13-.20
**Oil Specifications: S.A.E. No.	50	50	50	50	50	50
Water capacity, Industrial units, gals.	10	14	14	14	19	19
Permissible Governed Speeds: Continuous, full load	1500	1500	1500	1400	1400	1400
Permissible Governed Speeds: Intermittent, part load	2000	2000	2000	*2000	1800	1800
Valve tappet Setting, cold: Intake, inches	.008-.010	.008-.010	.008-.010	008-.010	.010-.012	.010-.012
Valve tappet Setting, cold: Exhaust, inches	.014-.016	.016-.018	.016-.018	.016-.018	.014-.016	.014-.016
Firing Order	1-5-3-6-2-4	1-5-3-6-2-4	1-5-3-6-2-4	1-5-3-6-2-4	1-5-3-6-2-4	1-5-3-6-2-4
Spark advance, maximum, flywheel, deg.	25°	27°	24°	28°	25°	29°
Dimension "A" (See paragraph 614)	4 1/4	4 1/2	4 1/2	4 1/2	......	......
Dimension "B" (See paragraph 621)	.005-.010	.005-.010	.005-.010	.005-.010	.005-.010	.005-.010
Dimension "C" (See paragraph 621)	.003-.005	.003-.005	.003-.005	.003-.005	.004-.006	.004-.006
Dimension "D" (See paragraph 621)	.010-.045	.010-.045	.010-.045	.010-.045	.060-.090	.060-.090

ENGINE MODEL	6GAL	6GAK	6EL	6EK	6RB	6LS	6LK	6LRO
Bore	5	5 1/2	6 1/2	7	5	7	7 3/4	8 1/2
Stroke	5 1/2	5 1/2	7	7	5 3/4	8 1/2	8 1/2	8 1/2
Displacement, cu. in.	648	784	1395	1616	677	1962	2406	2894
N.A.C.C. hp. rating (actual hp. higher)	60	72.5	101.4	117.7	60.0	117.6	144.0	173.4
Oil cap, qts., std. auto type oil pan	14		......		14	60	60	60
Oil capacity, qts., flat base stationary type	30		70		......	76	76	76
Oil pressure, lbs., 1500 rpm, hot	40		***40		40	***50	***50	***50
**Oil Specifications: Saybolt Viscosity @ 210° F.	75–105		75–105		75–105	105–125	105–125	105–125
**Oil Specifications: Kine visc. @ 210° F., poises	.13-.20		.13-.20		.13-.20	.20-.24	.20-.24	.20-.24
**Oil Specifications: S.A.E. No.	50		50		50	60	60	60
Water capacity Industrial units, gals.	....	17 3/4	45		19	62	62	62
Permissible Governed Speeds: Continuous, full load	1400		1050		1300	900	900	850
Permissible Governed Speeds: Intermittent, part load	1800		1125		*1900	1200	1200	1100
Valve tappet Setting, cold: Intake, inches	.010-.012		.012-.014		.006-.008	.012-.014	.012-.014	.020-.022
Valve tappet Setting, cold: Exhaust, inches	.014-.016		.020-.022		.010-.012	.020-.022	.020-.022	.026-.030
Firing Order	1-5-3-6-2-4		1-5-3-6-2-4		1-5-3-6-2-4	1-5-3-6-2-4	1-5-3-6-2-4	1-5-3-6-2-4
Spark advance, maximum, flywheel deg.	45°	....	....	28°	23°	25°	30°	40°
Dimension "A" (See paragraph 614)	4 7/8		6 5/8		5 7/16	7 3/4	7 3/4	......
Dimension "B" (See paragraph 621)	.008-.014		.009-.017		.005-.010	.010-.015	.010-.015	.010-.015
Dimension "C" (See paragraph 621)	.004-.007		.004-.010		.003-.005	009-.012	009-.012	.009-.012
Dimension "D" (See paragraph 621)	.085-.100		.091-.101		.030-.060	.060-.090	.060-.090	.060-.090

Kinematic viscosity of oils is given because it is the expectation that this method of expressing viscosity will become a universal standard. Saybolt viscosity is common in the United States, and has a limited use in other countries. The two systems are convertible, one to the other.

*Note—Top speeds marked with asterisk permissible only when aluminum pistons are used

**For Natural Gas Engines } Use Oil one grade lighter.
**For Winter Service }

***At Governed Speed.

REGULATION OF THE FLAME

The welding flame may be three kinds, namely, a carbonizing flame, a neutral flame and an oxidizing flame. While at first it appears difficult to recognize these flames, reference to Fig. 1 and a careful study of the characteristics of the flame will enable the operator to immediately recognize the proper flame and detect any variation. No fixed rule can be applied to the pressures of the two gases, however, the schedule as shown on the following page will serve as an approximate guide to the operator for the average run of work. Some operators, after considerable experience, desire an extremely long flame for certain classes of work. This requires higher gas pressures and it is then necessary to increase the pressures to give the desired flame.

In lighting the torch, open the acetylene valve until the acetylene gas is noted to be coming out at the tip, then light it at a gas jet, a spark lighter or other suitable means. Before lighting the gas, however, give it sufficient time to replace the air which is usually present in the hose and torch as this will eliminate the possibility of carbonizing the interior of the torch and thereby fouling it.

REGULATION OF THE FLAME

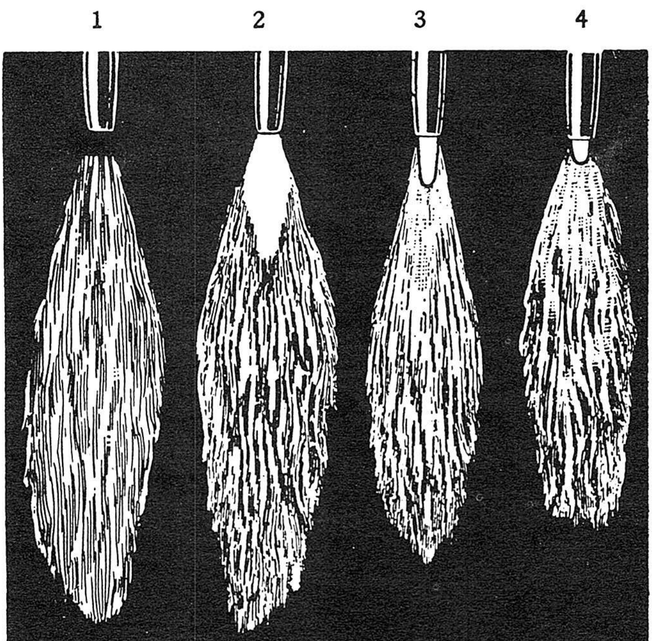


Fig. 1

Now increase the flow of acetylene gas by further opening the valve until the flame has the appearance of Flame No. 1, in Fig. 10, that is, the gas does not ignite until it has reached a point of about 3/16 of an inch from the end of the tip on a large tip and a much smaller distance on

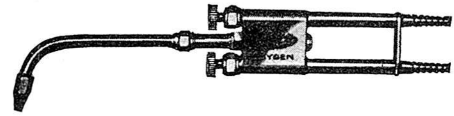
Continued on next page

a smaller tip. Now open the oxygen valve until the flame resembles that of Flame No. 2, which is known as a carbonizing flame. In this flame the yellow appearance disappears and it assumes a blue color with a long, roughly-pointed white cone. This flame is called a carbonizing flame since there is an insufficient supply of oxygen gas to completely burn up the acetylene gas.

Now further increase the supply of oxygen until the flame assumes the form of Flame No. 3. This is known as neutral flame and the one desired for practically all classes of welding work. Sufficient oxygen is supplied to completely burn all of the acetylene gas, and little or no effect should be noted on the material welded due to carbonization or oxidation where this flame is properly employed.

By supplying a further increase of oxygen the flame will assume the form of flame No. 4, which is known as an oxidizing flame and which is easily detected by the fact that the white cone or welding flame is choppy and the entire flame does not possess the clear apparance of flame No. 3.

A properly adjusted flame does not always continue to burn in a neutral manner, but may vary slightly with the operation of the regulators or with the temperature of the torch head. The operator must therefore continually watch his flame, making such adjustments as are necessary immediately at the time a variation is detected. Either a carbonizing or an oxidizing flame is detrimental to good welding. A carbonizing flame having a tendency to make the metal, especially mild steel, hard and brittle, and an oxidizing flame will burn up a part of the metal, producing a weak weld.



Type N. Lead Burning Torch

Turn on both tank valves adjusting the screws on both oxygen and acetylene regulators a few times until a pressure of a few pounds shows on the gauge. This will then blow out the hose, and any dirt that may have accumulated in packing or shipping will be dislodged from the hose. This is important as dirt clogs up the torch and makes good burning impossible. Then apply hose to torch, being sure that the proper hose is applied to the proper connections.

With the adjusting screw screwed in on the acetylene regulator so the gauge reads about two pounds and the adjusting screw screwed in on the oxygen regulator so that the gauge reads about two to five pounds open the acetylene valve on the torch and light. If the torch does not readily light and produces a blowing effect, the valve is opened too wide and must be closed a little. When the acetylene is lit and coming out of the torch in a fairly strong stream, the flame must not leave the tip. If too much force is applied to the flame, the flame will leave the tip and be lit from ⅛ to 1 inch away from the tip. To produce the best results we must have the flame start immediately at the tip.

Where low pressure city gas is used with the No. 2 or 2-A outfits, simply apply the flash-back to the gas line and apply the red hose to the outfit. A much higher oxygen pressure is required depending upon the size of tip used and intensity of flame required.

Always keep torch clean, as foreign matter getting into the same has a tendency to clog up and does not produce uniform results. If torch tip becomes clogged, a tip drill the size of the hole should be put in with the fingers, and this will clear the foreign matter.

WELDING KNOWLEDGE

In preparing a broken part for welding it is common practice to bevel the joint to be welded. This practice is well illustrated by Figs. 1 and 2. Lighter sections are beveled from one side only, as shown in Fig. 1 and heavier sections, where possible, are beveled from two sides, as shown in Fig. 2. This beveling is usually accomplished by means of grinding, chipping with a hammer and chisel, and in some cases machined off, or in many heavy, awkward pieces burned out with the torch flame. Burning out with the flame is strongly recommended against and is used only in cases where it is impossible to bevel by the first mentioned methods. Beveling has the further advantage of allowing the operator to begin the weld at the bottom of the break, thus preventing the possibility of a flaw in the weld.

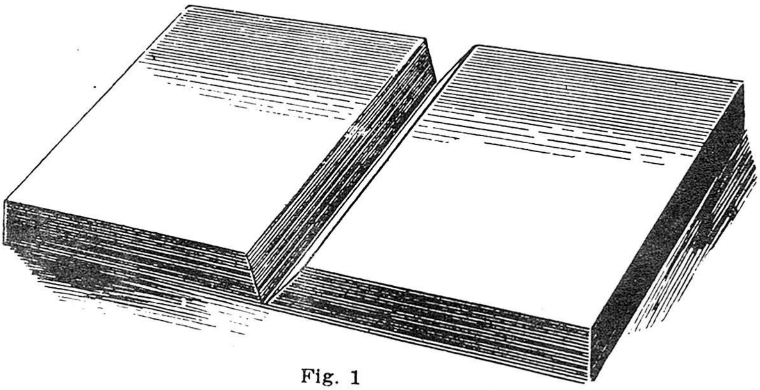


Fig. 1

This well illustrates the first and most essential lesson in welding, that is, TO WELD OR FUSE THE METAL AT THE POINT OF THE BREAK, AND THROUGH ITS ENTIRE THICKNESS, AND NOT SIMPLY ON THE SURFACE. This bevel, as a rule, is usually about 90°, however, it may be varied to suit the various welding conditions the operator is required to work under. The material used in filling up the space left by beveling is commonly termed the welding or filler rod. The quality of this rod is of utmost importance and sometimes becomes the success or failure of the weld. For smaller work 3/16 or ¼-inch diameter filler rods is sufficient; however, on large work a larger rod should be used, the size being governed entirely by experience and convenience of its use by the operator

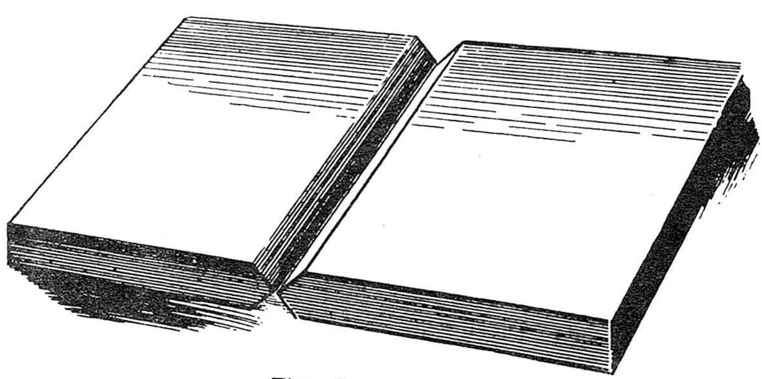


Fig. 2

In bringing the metals to their fusing point certain changes in their chemical analysis occur. Such elements as burn more readily have a tendency to oxidize and we find the use of a flux of considerable aid. A good flux should not only help cleanse and make the metal more fluid, but should also produce a protective coating over the molten metal to prevent unnecessary oxidation. The cost of MECO FLUX is so small in comparison with the value of good welds that it behooves the operator to adopt it and not experiment around with other cheap materials with which he is not familiar.

The different metals used in machinery production vary in melting point, have different co-efficients of heat conductivity and are of various thicknesses. These are the factors that positively govern the size of the flame to be used. No set rule can be given the inexperienced operator as to what size tip should be used for a particular job Too large a tip will melt the metal faster than the operator can control it and too small a tip will not melt quick enough, the heat being radiated to other parts of the casting faster than it is supplied by the flame. The following table, however, will assist the inexperienced operator greatly in giving the proper size tip he should use and enable him at least to make an intelligent start.

GAS PRESSURE FOR DIFFERENT SIZE TIPS

Tip No.	Thickness of Metal	Acetylene Pressure	Oxygen Pressure	Oxygen Consumption per Hour	Lineal Ft. Welded per Hour
1	1/32"	½ lb.	½ lb.	7.80	30 ft.
2	1/16"	1 "	1 "	7.90	25 "
3	3/32"	1 "	1½ "	8.10	20 "
4	1/8"	1 "	2 "	9.75	15 "
5	3/16"	1½ "	2½ "	16.80	9 "
6	5/16"	2 "	2½ "	26.40	6 "
7	3/8"	3 "	5 "	39.35	5 "
8	1/2"	5 "	8 "	51.15	4 "
9	5/8"	8 "	14 "	69.10	3
10	3/4" up	10 "	18 "	80.00	2

Note:—Consumption given above, taken with Hydrex Flow Indicator, with maximum size Flame. They are intended for estimating purposes only, and should amply cover adverse conditions.

EXPANSION AND CONTRACTION

The art of welding also brings us in contact with some of the old natural laws. The most essential being that of EXPANSION AND CONTRACTION, and one which the welder should not consider TOO LIGHTLY if he is to be successful. All metals, as we know, expand when heated, and contract when cooling, and while this law is a simple one it is sometimes extremely difficult to apply it in an intelligent manner to an irregular shaped casting. Cast iron, for example, is a very brittle metal, and if the strains caused by either expansion or contraction are not properly provided for a cracked casting will result.

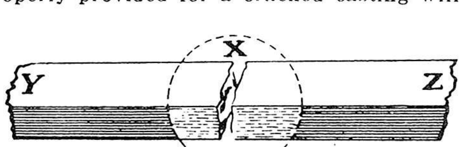


Fig. 3

To fully comprehend the principles of expansion and contraction, let us refer to Fig. 3. Here we have a rod or bar which is broken at X. If the weld is made no ill results will follow, since when the metal cools they are free to contract. Now refer to Fig. 4, in which case the broken bar is made the middle member of the frame with the break at the same location A. If we proceed to weld in the same manner as the previous figure we would find that as the metal at and surrounding the break A started to cool the ends D and E would not be free to contract since they are rigidly held by the members B and C, but had we previously heated members B and C until they expand the break at A will open up, the weld then be made and the frame allowed to cool with approximately an equal amount of contraction in each member. There are other means of offsetting the effects of expansion and contraction than heating, and certain metals require no safeguards whatever.

Not all parts are as simply handled as the one just illustrated. For example, take the case where a light section must be welded to a heavier one. In this case it is extremely important that the operator divide the heat from the flame between these two members in such a proportion as will render them both to approximately the same temperature and not bring one to the fusing temperature at the expense of the other. A little study and experience with individual cases should bring the operator to understand the principles of expansion and contraction and teach him that metals will expand when heated and contract when cooling in spite of the use of clamps, vises or other paraphernalia.

A good example of this would be to fix the ends of Y and Z of the broken bar as illustrated in Fig. 3. To be sure these ends would not expand if the weld was made at X, but the expansion, however, would take place from both ends toward the center, as this would be the easiest way; however, since the cold metal would occupy a smaller space than the heated metal, the weld would break on cooling. Clamps or bolts may be used to secure alginment or guide expansion, but never be used to prevent expansion, as this is absolutely impossible.

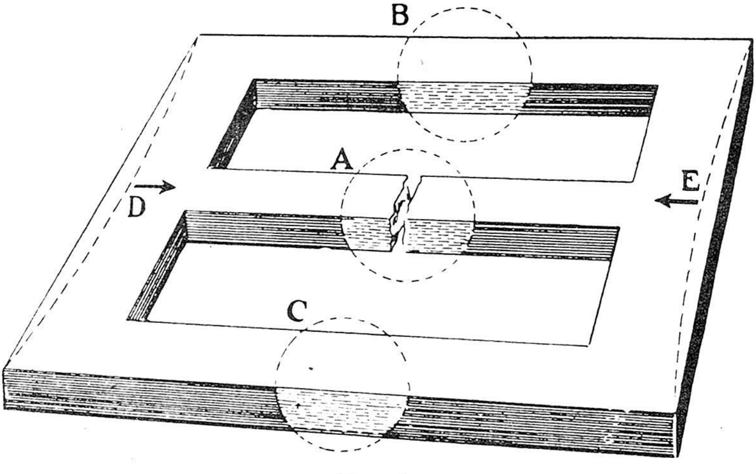


Fig. 4.

Failure to understand and apply the law of expansion and contraction is absolutely responsible for the failure of most repair welders. Each particular job should be studied and the principles applied before attempting the actual welding itself. Determine where the strain will be set up and then overcome this strain before executing the weld. The following tables will serve to give the operator the relative coefficience of linear expansion, of heat conductivity and the melting or fusing points of the various metals he will come in contact with.

CO-EFFICIENTS OF LINEAR EXPANSION

Aluminum (cast)	.00001234
Cast Iron	.00000617
Steel (untempered)	.00000599
Steel (tempered)	.00000702
Copper	.00000955
Brass (cast)	.00001037
Silver	.00001060
Wrought Iron	.00000686
Lead	.00001571
Zinc	.00001634
Tin	.00001230

HEAT CONDUCTIVITY OF METALS

Silver	100.00
Copper	73.6
Gold	53.2
Aluminum	31.3
Brass	23.1
Zinc	19.0
Tin	14.5
Iron	11.9
Steel	11.6
Lead	8.5
Platinum	8.4

MELTING POINTS OF METALS

Wrought Iron	2730 Degrees F.
Nickel	2703 Degrees F.
Mild Steel	2680 Degrees F.
Hard Steel	2552 Degrees F.
Grey Cast Iron	2192 Degrees F.
White Cast Iron	2012 Degrees F.
Aluminum	1212 Degrees F.
Copper	1947 Degrees F

As fly wheels and pulleys are a common type of work to be welded and as so few understand the proper method of handling them, the following will be of great assistance. This applies to the building of teeth on gear wheels for any type of wheel having only a hub and rim with spokes between. A great many wheels have a web between hub and rim. These must, as a rule, be preheated all over, unless the general idea of the following can be carried out:

As an example of taking care of expansion and contraction by the application of heat locally, consider Fig. 5, which represents a fly-wheel or pulley with broken spokes. Assuming that it is broken only at a point "A," we know that were we to weld this spoke without considering expansion or contraction the shrinkage strain would be so great that failure would occur.

Preheating the rim from W to X to a dull red heat will cause it to expand outwardly, separating the edges of the broken spoke. While in this state the weld should be rapidly made and the whole wheel allowed to cool slowly. Thus a good weld without the presence of internal strains will be produced. The expansion of the rim will offset the contraction of the weld in the spoke.

If the crack in the spoke is near the rim it is only necessary to apply a gas or oil burner to the rim at "M" until it is red hot. This will expand the spoke and rim and separate the edges of the break sufficiently to offset the contraction of the weld.

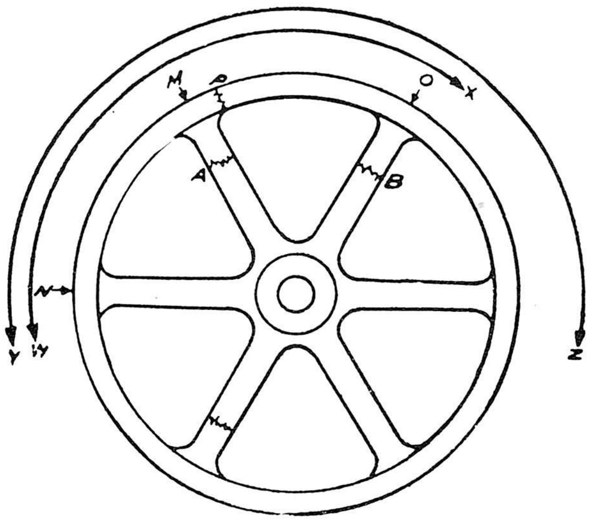


Fig. 5

As an example of making proper allowance for expansion and contraction without heating, this spoke may be also welded "cold," that is without any auxiliary heating. It is necessary that the rigidity of the rim be lessened, and in order to do this it is broken at a point "P," always close to the spoke. First one side of the spoke is strongly "Tacked" with the blowpipe at the weld. Then the other side is welded half through. The tack is then melted out and this side welded. If the weld has carried entirely through the spoke in one continuous operation, the contraction of the finished weld would be such that the rim would be out of "Round." Therefore, it is necessary that the original spacing be retained. The rim is now welded at the point "P." If the edges do not meet accurately, they may be brought to do so by heating either at point "M" or "O," according to which edge is low, and then welded.

If there are two spokes broken as at "A" and "B" the same general procedure as given above may be followed.

In case it is necessary to preheat a large portion of the casting it is important that the preheated area always extend past the spokes adjacent to those fractured as shown by "Y"—"Z." If two diametrically opposed spokes such as "B" and "C" are broken, each spoke may be treated as independent of the other and welded by any of the methods previously described.

Before attempting to do actual repair work, it is best to practice on scrap materials. Make the welds and then break them through the weld. You can then see for yourself the kind of weld you are making and you will have further learned to operate the torch properly before attempting serious work. It is best to practice on metal ⅛" to ¼" in thickness as less gas is required to make the weld.

CAST IRON

Bevel the ends of the test pieces as previously explained and place them in position for welding. The edges should be slightly separated to allow for contraction; about 1-32-inch will be found about correct. Use the size tips recommended on the Table, Page 99 Special care should be used to heat the piece slowly. This is best done by moving the flame in a circle as illustrated in Fig. 6. When the metal becomes red for a distance of about three times as the metal is thick

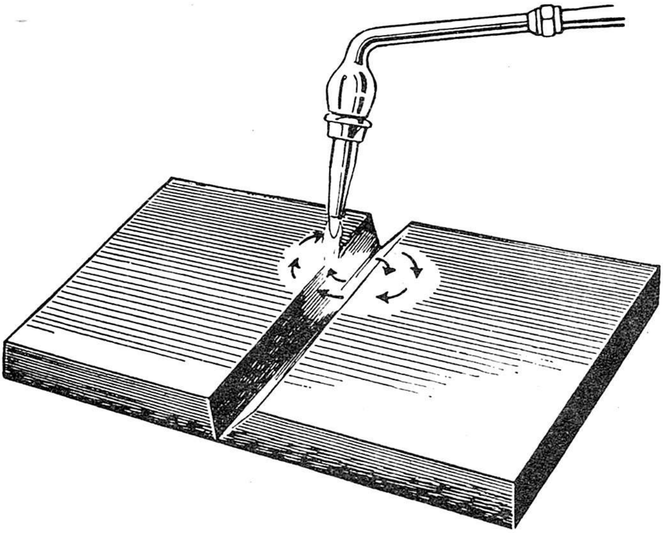


Fig. 6

we are ready to begin the welding operation. Have the Cast Iron Flux in convenient reach and with the filler rod in one hand and the torch in the other, bring the welding flame down to the metal until the end of the cone is almost, but not quite, touching the edges, as illustrated in Fig. 7. The welding rod is placed near the flame to slightly heat it—then it is dipped in the flux can and the flux picked up by the hot rod is placed in the spot the flame is playing upon. Usually this is sufficient to break the film of oxide and to cause the metal to flow together. Note that we have added no material from the welding rod as yet. Now we melt the SIDES of the break and flow them towards the bottom until the weld has the general appearance of Fig. 8. Then we are ready to use the material from the welding rod, which should be kept in contact with the weld at all times to avoid loss of heat. REMEMBER THAT THE ARTICLE AND THE WELDING ROD ARE THE SAME METALS, MELTING AT THE SAME TEMPERATURE. We must, then, keep the article and the rod in fusion at all times to effect a bond. Be very careful that the metal is actually melting while the rod is being added.

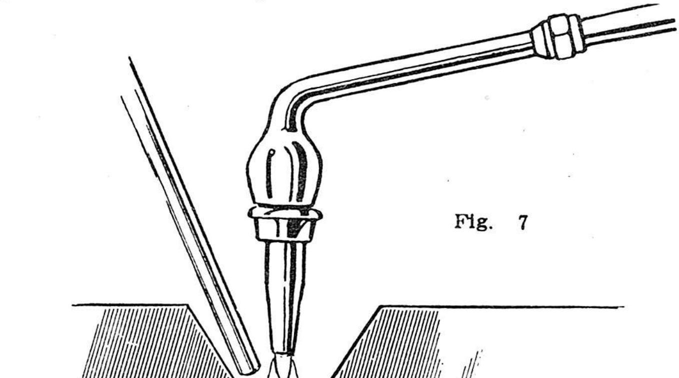


Fig. 7

Avoid the habit of pulling the torch away from the weld—rather use a slow circular movement which insures fusion and does away with loss of heat. Use the flux sparingly—never throwing it in with the hands—the amount picked up by the hot welding rod is sufficient at all times. At times it may be necessary to break the oxide by stirring the molten iron with the rod, and if the metal is very dirty, by pulling it out of the line of welding by means of the rod.

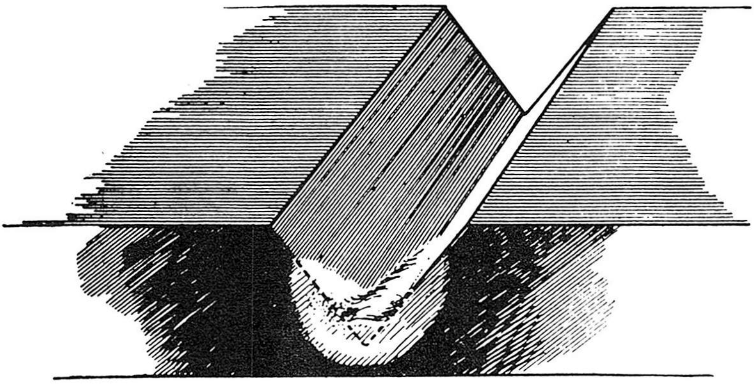


Fig. 8

As we progress with the welding we note that the metal does not always flow where we want it to, i. e., where we are holding the flame. The force of the flame usually prevents this and we add the metal from the welding rod at a point a little distance away from where we actually want it to flow, and when we are ready to have it join the casting we remove the flame from that point and swing the metal to the section desired by the circular motion described.

Cast iron does not immediately solidify the moment the flame is removed—it remains liquid for some little time and this condition presents two difficulties: one the danger of allowing this fluid metal to flow over, without bonding to the other metal, and the other the collapsing of the weld. The first difficulty may be offset by watching the weld carefully and bringing all parts into fusion. The second one is usually experienced by beginners and is caused by their lack of knowledge of the metal and the force of the flame with the metal in a liquid condition, is sufficient to cause the metal to collapse and create a hole.

One of the reasons for the collapse is the force or velocity of the flame—the metal is fluid all the way through and this force is sufficient to let it drop. We must, therefore, have a solid base at all times, which may be secured by the circular motion of the welding torch—not keeping the flame in one spot too long. To fill a hole, work down the sides the same as we have done in starting the weld, then dip the torch on an angle, as illustrated in Fig. 9, being careful, however, to keep the metal in fusion all the time. The idea is to divert the direction of the force of the flame. This same method is applicable where small sections may be missing.

If we have carefully followed out the directions, we should have a joint which is even stronger than the original article, and we can make it considerably stronger by adding additional metal to the line of welding.

WELDING STEEL

Preparation for the steel weld is practically the same as for Cast Iron. When the steel is heated sufficiently to begin welding, we bring

Shop Equipment Directory

In this Department, we have assembled and classified representative manufacturers and supply sources covering many lines of Shop Equipment, Machine Parts, Tools and Materials. These Manufacturers and Distributors will promptly supply additional detailed information on request. When writing Manufacturers, please mention UNIVERSAL MACHINISTS' HANDBOOK.

ABRASIVES, Cloth and Paper
Abrasive Prod., Inc., So. Braintree, Mass.
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Schultz & Anderson Co., Newark, N. J.
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Keystone Grinder & Mfg. Co., Pittsburgh 19, Pa.

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AIR-WAY PUMP & EQUIPMENT CO.
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Chicago 51, Ill.
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AIR PUMPS
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AIR PURIFIERS, (Compressed)
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ALLOYS
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AMMONIA
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The Ohio Nut & Washer Co.
Mingo Junction, Ohio

BADGES

SUPERIOR SEAL & STAMP CO.
1402 Vermont Ave.
Detroit 16, Mich.
Brass, Zinc, Aluminum Tool Checks, Name, Machine, Number Plates, Property and Inventory Tags, Employee Badges.

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Atlantic Saw Mfg. Co., New Haven, Conn.
Atlas Press Co., Kalamazoo, Mich.
Continental Machines, Inc., Minneapolis,
Racine Tool & Mach. Co., Racine, Wis.
Tannewitz Works, Grand Rapids, Mich.

BARS, Boring
Adamas Carbide Corp., Harrison, N. J.
Armstrong Bros. Mfg. Co., Chicago, Ill.
Davis Boring Tool Div., St. Louis, Mo.
Elk Tools, Incorporated, New York 7, N. Y.
The Gairing Tool Co., Detroit 32, Mich.
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BEARINGS, Ball
Abbott Ball Co., Hartford, Conn.
Ahlberg Bearing Co., Chicago, Ill.
McGill Mfg. Co., Valparaiso, Ind.
Miniature Precision Bearings, Inc., Keene, N. H.
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BEARINGS, Roller
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Rockwood Mfg. Co., Inc., Indianapolis 6, Ind.

"BELT-Pull"
Rockwood Mfg. Co., Inc., Indianapolis 6, Ind.

BENCHES, Factory
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Pollard Bros. Mfg. Co., Chicago 30, Ill.
Standard Presser Steel, Jenkintown, Pa.

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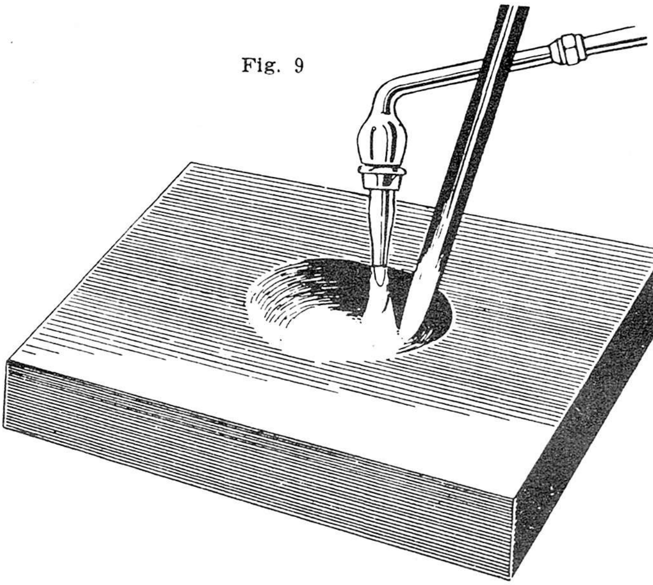
Buffalo Forge Co., Buffalo, N. Y.
Cleveland Crane & Engr. Co., Wickliffe, O.
Excelsior Tool & M. Co., E. St. Louis, Ill.
Hossfeld Mfg. Co., Winona, Minn.

the cone down as shown in Fig. 10 until the end of it just about touches the surfaces to be joined. Do not make the mistake of bringing the tip of the torch to the metal—hold the torch so that the end of the cone just LICKS the surface.

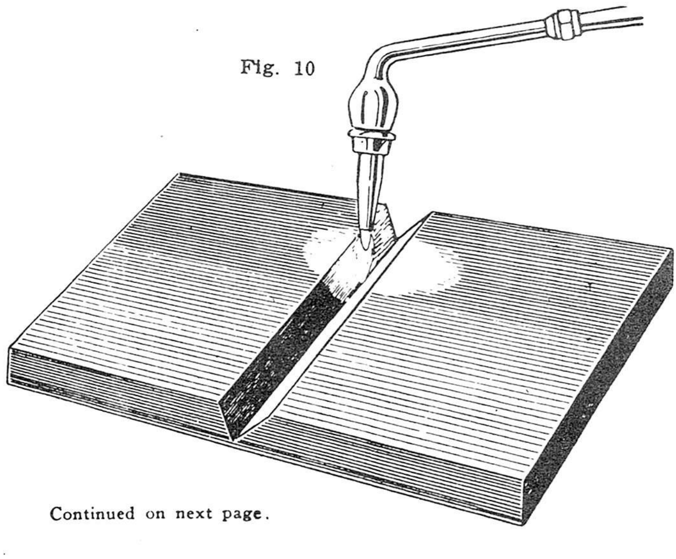
Fig. 9



As the bottom of the metal melts together, the welding rod is brought down until it touches that spot and a small portion of it is melted while it is in contact with the material, as in Fig. 11,.

Now, we fuse this small portion to the material by a short circular motion, making sure that the flame actually comes in contact with every portion of it and that it is thoroughly fused to the material and that it has penetrated. As we finish the circular motion, we start melting the spot immediately adjoining.

Fig. 10



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Rock River Mach. Co., Chicago, Ill.

BITS
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New York 7, N. Y.

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John H. Graham & Co., Inc., New York 8, N. Y.
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Spartan Saw Works, Springfield, Mass.
The L. S. Starrett Co., Athol, Mass.
H. G. Thompson Sons, New Haven, Conn.
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American Air Filter Co., Louisville, Ky.
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BORING MILLS, Bench Model

BORING MILLS, Bench Model Horizontal
Multiple Boring Machine Co., St. Louis, Mo.

BORING TOOLS
Adamas Carbide Corp., Harrison, N. J.
Armstrong Bros. Tool Co., Chicago, Ill.
Bokum Tool Co., Detroit, Mich.
Davis Boring Tool Co., St. Louis, Mo.
The Gairing Tool Co., Detroit 32, Mich.
Russell Boring Bar Co. Middletown, Ohio
Van Norman M. Tool, Springfield, Mass.

BORING AND TURNING MILLS
Cincinnati Planer Co., Cincinnati, Ohio
Ganey Machinery Co., Buffalo, N. Y.
The New Britain Machine Co., New Britain, Conn.
Lucas Machine Div. of The New Britain Machine Co., New Britain, Conn.
New Britain-Gridley Machine Div. of New Britain Machine Co., New Britain, Conn.
King Machine Tool Div. of American Steel Foundries, Cincinnati 29, Ohio
Yoder Sales Co., Cleveland, Ohio

BRAKES, Hand and Power
Dreis & Krump Mfg. Co., Chicago, Ill.
Excelsior Tool and Machine Co., East St. Louis, Ill.
O'Neil-Irwin Mfg. Co., Minneapolis
United States Steel Supply Co., Chicago 4, Ill.
United States Steel Corp. Subsidiary
Verson Allsteel Press Co., Chicago, Ill.
Whitney Metal Tool Co., Rockford, Ill.

BROACHES, Keyway
East Shore Mach. Prod. Co., Cleveland, O.

BROACHING MACHINES
Amer. Broach & Mach. Co., Ann Arbor
Colonial Broach Co., Detroit, Mich.
Detroit Broach Co., Detroit, Mich.
East Shore Mach. Prod. Co., Cleveland, O.
National Broach & Mach., Detroit, Mich.
Oilgear Corp., Milwaukee, Wis.
The du Mont Corp., Greenfield, Mass.

BUFFING AND POLISHING
Standard Elec. Tool Co., Cincinnati, O.
Vonnegut Moulder Corp., Indianapolis 2, Ind.

BULLDOZERS
Beatty Mfg. & Mach. Co., Hammond, Ind.
Rock River Mach. Co., Chicago, Ill.

BUSHINGS, Brass and Bronze
Bunting Brass & Bronze Co., Toledo, O.
Federal-Mogul Corp., Detroit, Mich.
Johnson Bronze Co., New Castle, Pa.
Keystone Carbon Co., St. Marys, Pa.
Phosfer Bronze Smelt. Co., Philadelphia

BUSHINGS, Drill
W. F. Meyers Co., Inc., Bedford, Ind.

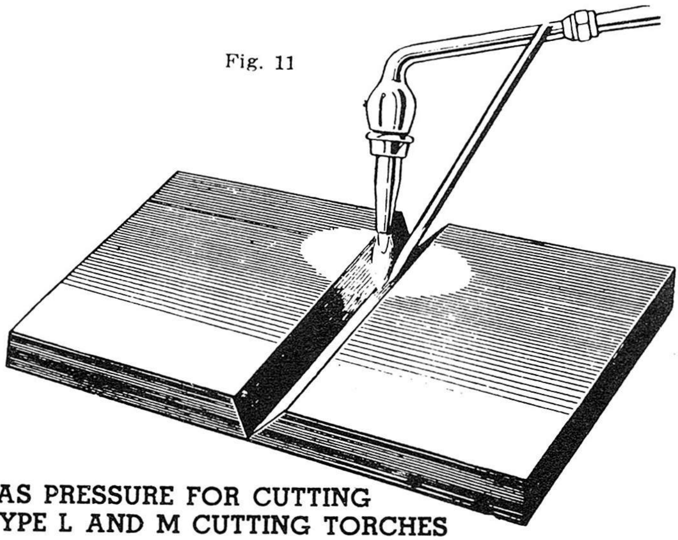
CALIPERS
Banner Mach. Tool & Supply Co., St. Louis 7, Mo.
Belf & Lustig, New York, N. Y.
Brown & Sharpe Mfg. Co., Providence
Federal Products Corp., Providence 1, R. I.
Guedon Co., Audubon, N. J.
Lufkin Rule Co., Saginaw, Mich.
Park Sales Co., New York, N. Y.
The L. S. Starrett Co., Athol, Mass.

CARBIDE, Tipped Reamers
Wendt-Sonis Co., Hannibal, Mo.

Unlike cast iron, steel does not remain a liquid—it solidifies almost the instant the flame is removed, and it is for this reason that we are able to weld it in a vertical or overhead position, as well as horizontal.

If there is an excess of sparks, the flame is improperly adjusted and contains an excess of oxygen. If the metal melts too rapidly and is difficult to control, the tip is too large. If it does not keep in fusion and there is difficulty in getting the welding rod material to actually fuse to the article, the tip is too small. The beginner will be troubled with the welding rod sticking to the metal—don't attempt to pull it away; let it stay here until it is necessary to melt a portion of it in the weld.

Fig. 11



GAS PRESSURE FOR CUTTING WITH TYPE L AND M CUTTING TORCHES

Tip No.	Thickness of Metal, Inches	Acetylene Press., Lbs.	Oxygen Press., Lbs.	Acetylene Consumption Cu. Ft. Per Hr.	Oxygen Consumption Cu. Ft. Per Hr.
L-1	1/8	4	10	9.50	35
L-1	1/4	4	15	9.50	40
L-1	3/8	4	20	9.50	45
L-1	1/2	4	25	9.50	50
L-2	3/4	5	30	15.30	60
L-2	1	5	40	15.30	100
L-2	1 1/2	5	50	15.30	150
L-2	2	5	60	15.30	200
L-3	3	6	70	25.20	275
L-3	4	6	80	25.20	350
L-3	5	6	90	25.20	425
L-4	6	7	100	27.30	550
L-4	8	7	130	27.30	825
L-4	10	8	150	28.20	1000

NOTE:—Consumption of gases given above was taken with flow indicator and estimated for continuous operation of the torch. These figures will seldom be reached in actual practice and are intended for estimating purposes only.

LIGHTING THE TORCH

Above table gives the approximate pressure of both Acetylene and Oxygen for cutting different thicknesses of metal. This, however, can only be used as a guide, as metal will rust on its surface, or metal

CARBIDE, Tool Bits
Wendt-Sonis Co. Hannibal, Mo.

CATERPILLAR TRACTOR
Caterpillar Tractor Co., Peoria, Ill.

CENTERS
Pratt & Whitney, West Hartford, Conn.

CENTERING MACHINES
Ex-Cell-O Corp., Detroit, Mich.
Jones & Lamson Co., Springfield, Vt.
Pratt & Whitney, West Hartford, Conn.
Sundstrand Mach. Tool Co., Rockford, Ill.

CHAIN DRIVES
Cullman Wheel Co., Chicago, Ill.
Morse Chain Co., Ithaca, N. Y.
Potter & Johnston Co., Pawtucket, R. I.
Whitney Mfg. Co., Hartford, Conn.

CHEMICALS
Du Pont De Nemours & Co., Inc., E. I. Chemical Products, Wilmington, Del.
Mallinckrodt Chemical Works, Industrial Chemicals, St. Louis, Mo.
Monsanto Chemical Co., Chemicals & Plastics Serving Industries, St. Louis, Mo.

CHESTS, Tool
H. Gerstner & Sons, Dayton, Ohio
The Vanderman Mfg. Co., Willimantic, Conn.

CHISELS
Banner Mach. Tool & Supply Co., St. Louis 7, Mo.
Delaware Tool Steel Corp., Wilmington 99, Delaware
Millers Falls Co., Greenfield, Mass.

CHISELS, Carpenter
Winsted Edge Tool Works, Winsted, Conn.

CHUCKING MACHINES
Bell Machine Co. Oshkosh, Wis.
J. W. Bullard Co., Bridgeport, Conn.
Foster Machine Co., Elkhart, Ind.
Gisholt Machine Co., Madison 10, Wis.
Jones & Lamson Co., Springfield, Vt.
The New Britain Machine Co., New Britain, Conn.
Lucas Machine Div. of The New Britain Machine Co., New Britain, Conn.
New Britain-Gridley Machine Div. of New Britain Machine Co., New Britain, Conn.
Potter & Johnston Co., Pawtucket, R. I.
Sundstrand Mach. Tool Co., Rockford, Ill.

CHUCKS, Air
Cushman Chuck Co., Hartford, Conn.
Gisholt Machine Co., Madison 10, Wis.
Hannifan Mfg. Co., Chicago, Ill.
Leiman Bros., Inc., Newark 5, N. J.
Logansport Machine Co., Inc., Logansport, Ind.
Skinner Chuck Co., New Britain, Conn.

CHUCKS, Drill and Tap
Alco Tool Co., Bridgeport, Conn.
T. R. Almond Mfg. Co., Ashburnham, Mass.
Chicago Tool & Engr. Co., Chicago, Ill.
Erickson Steel Co., Cleveland, Ohio
Ettco Tool Co., Brooklyn, N. Y.
Jacobs Mfg. Co., Hartford, Conn.
The Kett Tool Co., Cincinnati 2, Ohio
K. O. Lee & Son, Aberdeen, S. D.
Modern Tool Works, Rochester, N. Y.
Motor Tool Mfg. Co., Detroit, Mich.
Procunier Safety Chuck Co., Chicago, Ill

CHUCKS, Lathe
T. R. Almond Mfg. Co., Ashburnham, Mass.
Gisholt Machine Co., Madison 10, Wis.
L-W Chuck Co., Toledo, Ohio
Morrison Mach. Prod. Div., Elmira, N. Y.
Skinner Chuck Co., New Britain, Conn.
Thomas Hoist Co., Chicago, Ill.
Universal Engr. Co., Frankenmuth, Mich.
Westcott Chuck Co., Oneida, N. Y.

AIR-OPERATED CLAMPS
Lapeer Mfg. Co., Lapeer, Mich.

CLAMPS AND CLAMPING DEVICES
Armstrong Bros. Tool Co., Chicago, Ill.
Batavia Clamp Co., Batavia, N. Y.
Brownie Mfg. Corp., Huntington, Ind.
Cincinnati Tool Co., Cincinnati, Ohio
Detroit Stamping Co., Detroit, Mich.
Grand Specialties Co., Chicago 22, Ill.
Lapeer Mfg. Co., Lapeer, Mich.
Howell Clamp Co., Cleveland, Ohio
K-O Products Co., Benton Harbor, Mich.
Mead Specialties Co., Chicago, Ill.
Richards' Industries, Inc., Grand Rapids 5, Mich.
Rivett Lathe & Grinder Co., Boston, Mass.
United States Steel Supply Co., Chicago 4, Ill.
United States Steel Corp. Subsidiary
Sales Service Machine Tool Co., Saint Paul W4, Minn.

CLUTCHES
Brown Engineering Co., Reading, Pa.
Carlyle Johnson M. Co., Manchester, Con.
L. W. Carroll Mfg. Co., Norwood, Cincinnati, Ohio
Conway Clutch Co., Cincinnati, Ohio
Twin Disc Clutch Co., Racine, Wis.

COLLETS
Brown & Sharpe Mfg., Providence, R. I.
Hardinge Bros. Inc., Elmira, N. Y.
Chas. L. Jarvis Co., Middleton, Conn.
Modern Collet & Mach. Co., Ecorse, Mich.
Rivett Lathe & Grinder Co., Boston, Mass.

COMPRESSORS, Air
Chicago Pneu. Tool Co., New York, N. Y.
Curtis Pneu. Mchy. Co., St. Louis, Mo.
Hobart Bros. Co., Troy, Ohio
Ingersoll Rand Co., New York, N. Y.

CONTRACT WORK
Amer. Pattern & Model Co., St. Louis, Mo.
Ballak & Company, St. Louis, Mo.
Friede Welding Co., St. Louis, Mo.
Hartford Spec. Machy. Co., Hartford
Jefferson Mach. Tool Co., Cincinnati, O.
Liberty Foundry Co., St. Louis, Mo.
Liberty Tool & Gage Wks., Providence
Mack Specialty Co., St. Louis, Mo.
Peters Tool Co., Milwaukee, Wis.
Quality Tool & Die Co., Indianapolis, Ind.
Severance Tool Mfg. Co., Saginaw, Mich.
Swanson Tool & Machine Products, Inc., Erie, Pa.
Taylor Machine Co., Cleveland, Ohio
Westlof Tool & Die Co., Detroit, Mich.
Wittek Mfg. Co., Chicago, Ill.

CONTROLS AND CONTROLLERS
Acme Industrial Co., Chicago, Ill.
Clark Controller Co., Cleveland, Ohio
General Electric Co., Schenectady, N. Y.

Continued

CUTTING STEEL

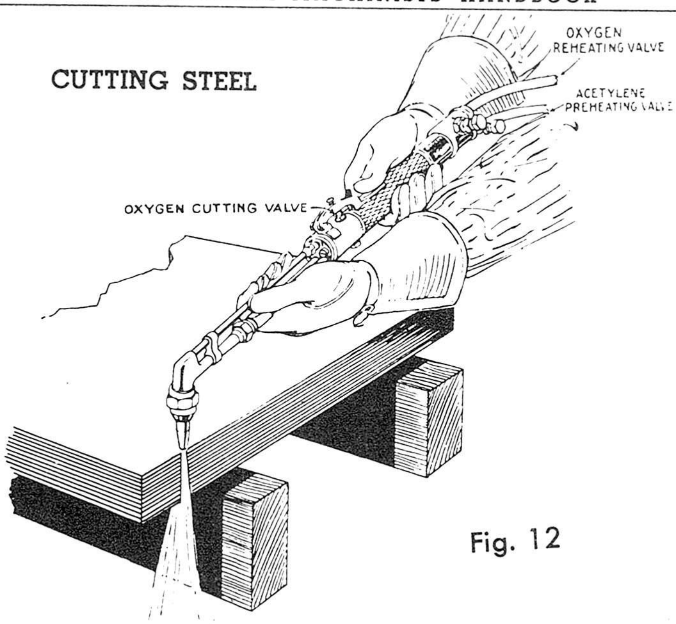


Fig. 12

Hold the torch as illustrated in Figure 12 to one corner of the plate to be cut. When this corner becomes red, open the oxygen cutting valve by pressing down with the thumb. The steel will immediately begin to burn and assume an incandescent heat. The torch must now be moved evenly along the line of cut to maintain this incandescent heat. If the torch is moved too slowly or if moved too fast you will lose this heat and the torch will cease to cut. It is then necessary to turn off the oxygen cutting valve and heat up the end of the cut to the bright red heat and begin over. Beginners as a rule have some trouble, as it requires some practice to move the torch at even pace.

Figure 26 illustrates the wrong method of cutting. It will be noted that the sparks instead of flying directly downward are turned at an angle, showing that the cut is not going through the metal. This also causes a part of the molten metal and flame to be blown against the torch, and will cause trouble.

The torch head should also be inclined about 5 degrees from the perpendicular to the reverse direction of the cut. This partly overcomes the trouble in Figure 13 and leaves straighter lines on the sides of the curf.

Figure 14 illustrates the torch working properly and cutting entirely through the metal. Always be sure that this is done and you will have no trouble.

Sometimes it is necessary to start a cut in the middle of a sheet. It is then well to hold the preheating flame within about ⅛ of an inch of the metal until it becomes red, then lift the torch slightly and turn on the Oxygen Cutting Valve. The steel will immediately begin to burn and the hole will soon be through. This is also to be followed when it is necessary to cut one sheet riveted on to another.

Always see that the surface of the metal is as clean as possible before attempting to cut it. Old boilers especially should be struck sharply with a hammer along the line of proposed cut, in order to loosen the scale which adheres to the inside.

CONTROLS AND CONTROLLERS

Logansport Machine Co., Inc., Logansport, Ind

Vickers Incorporated, Detroit, Mich.
Westinghouse Elec. Co., E. Pittsburgh, Pa.

COUNTERBORES & COUNTERSINKS

Aero Tool Co., Los Angeles 3, Calif.
Cleveland Twist Drill Co., Cleveland, Ohio
Gairing Tool Co., Detroit, Mich.
J. C. Glenzer Co., Detroit, Mich.
Midwest Tool & Mfg. Co., Detroit, Mich.
National Twist Drill Co., Detroit, Mich.
Putnam Tool Co., Detroit, Mich.
Severance Tool Mfg. Co., Saginaw, Mich.

COUNTING DEVICES

Durant Mfg. Co., Milwaukee, Wis.
Veeder Root, Inc., Hartford, Conn.

COUPLINGS

Guardian Utilities Co., Michigan City, Ind.
Lovejoy Flex. Coupling Co., Chicago Ill.

Multiple Boring Machine Co., St. Louis, Mo.

Smith Power Transmission Co., Cleveland

CRANES

Shaw Box Crane & Hoist, Muskegon, Mich.

CUT-OFF MACHINES

Boice Crane Co., Toledo, Ohio
Catskill Metal Works, Catskill, N. Y.
Delta Mfg. Co., Milwaukee, Wis.
DeWalt, Inc., Lancaster, Pa.
Modern Mach. Tool Co., Jackson, Mich.
Porter-McLeod Mach. Tool Co., Hatfield
Rickert-Shafer Co., Erie, Pa.
Tannewitz Works, Grand Rapids, Mich.
Walker-Turner Co., Plainfield, N. J.

CYLINDERS, Air

ANKER-HOLTH MANUFACTURING CO.
2723 Conners St.
Port Huron, Mich.

Air Cylinders, Rotating — Non-Rotating. Any bore, stroke, or mounting.

Bell Machine Co., Oshkosh, Wis.
Galland-Henning Mfg. Co., Milwaukee.
Hannifin Mfg. Co., Chicago, Ill.
Logansport Machine Co., Inc., Logansport, Ind

Tomkins-Johnson Co., Jackson, Mich.

ANKER-HOLTH MANUFACTURING CO.
2723 Conners St.
Port Huron, Mich.

Hydraulic Cylinders. Any bore, stroke, or mounting available up to 5000 PSI.

CYLINDERS, Hydraulic

ANKER-HOLTH MANUFACTURING CO.
2723 Conners St.
Port Huron, Mich.

Hanna Engineering Wks., Chicago, Ill.

Logansport Machine Co., Inc., Logansport, Ind

CYLINDERS, Welding

Independent Eng. Co., O'Fallon, Ill.

DEMAGNETIZERS

Alofs Mfg. Co., Grand Rapids, Mich.
R. B. Annis Co., Indianapolis, Ind.
Electro-Matic Prod. Co., Chicago, Ill.
Luma Elec. Equip. Co., Toledo, Ohio

Welch Industries, Inc., Colorado Springs, Colo.

DIALS

Miller Dial & Name Plate Co., Los Angeles 21, Calif.

DIAMONDS AND DIAMOND TOOLS

Abrasive Dressg. Tool Co., Detroit, Mich.
Acme Diamond Tool Co., New York, N. Y.
Diamond Tool Co., Chicago, Ill.
Doebel Diamond Tool Co., Detroit, Mich.
Golconda Diamond Prod. Co., Chicago, Ill.
E. Karelsen, Inc., New York, N. Y.
J. K. Smit & Sons, New York, N. Y.

Willeys Carbide Tool Co., Detroit, Mich.

DIE CUSHIONS

Dayton Rogers Mfg. Co., Minneapolis
Verson Allsteel Press Co., Chicago, Ill.

DIE, Guide

Lassy Tool Corp., Plainville, Conn.

DIE FILERS

Armglo Company, Milwaukee, Wis.

DIE HEADS

Modern Tool Works, Rochester, N. Y.
Murchey Mach. & Tool Co., Detroit, Mich.
Rickert-Shafer Co., Erie, Pa.

DIE MAKING MACHINES

Continental Machines, Inc., Minneapolis
Foley Mfg. Co., Minneapolis, Minn.
Fray Mach. Tool Co., Glendale, Calif.
Hack Machine Co., Desplaines, Ill.
Harvey Mfg. Co., New York, N. Y.
Kearney & Trecker Corp., Milwaukee

Pratt & Whitney, West Hartford, Conn.

DIE AND TAP SETS

Baumbach Mfg. Co., Chicago, Ill.
Danly Mach. Specialties, Cicero, Ill.
Greenfield Tap & Die, Greenfield, Mass.
Producto Machine Co., Bridgeport, Conn.

DIES, Threading

Banner Machine Tool Co., St. Louis, Mo.
Champion Blower & Forge Co., Lancaster, Pa.
E. Mach. Screw Corp., New Haven, Conn.
Geometric Tool Co., New Haven Conn.
Greenfield Tap & Die Corp., Greenfield
National Acme, Cleveland, Ohio
Rickert-Shafer Co., Erie, Pa.

Winter Bros. Co., Wrentham, Mass.

DIES, Thread Rolling

Reed Roller Thread Die Co., Worchester 2, Mass.

DIVIDING HEADS

Wm. Carroll & Son, Cincinnati, Ohio
Hart Machine Co., Boston, Mass.
Jefferson Mach. Tool Co., Cincinnati, O.
W. B. Knight Machy. Co., St. Louis, Mo.
N. Britain T. & Mfg., New Britain, Conn.

Nichols-Morris Corp.,
50 Church Street, New York 7, N. Y.

DOWEL AND ASSEMBLY PINS

Acme Industrial Co., Chicago, Ill.
The Helm Co., Fairfield, Conn.

DRAWING KNIVES, Carpenter

Winsted Edge Tool Works, Winsted, Conn.

DRESSERS

Carboloy Co., Detroit, Mich.
Desmond-Stephan Mfg. Co., Urbana, Ohio
E. Karelsen, Inc., New York, N. Y.

K. O. Lee & Son, Aberdeen, S. D.
M & S Dresser Co., Hartford, Conn.
W. F. Meyers Co., Inc., Bedford, Ind.
Vincent Steel Prod. Co., Detroit, Mich.
Welch Industries, Inc., Detroit, Mich.
Western Tool & Mfg. Co., Springfield, O.
Willeys Carbide Tool Co., Detroit, Mich.

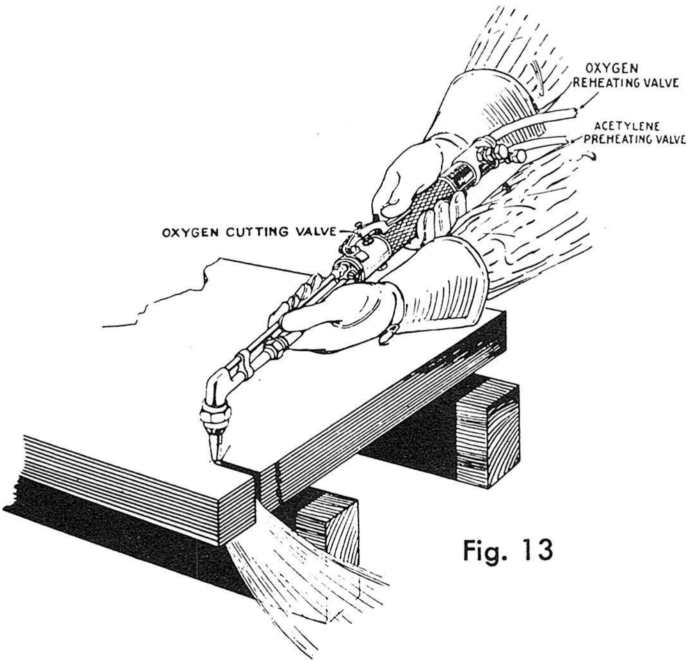

OXYGEN
REHEATING VALVE
ACETYLENE
PREHEATING VALVE
OXYGEN CUTTING VALVE

Fig. 13

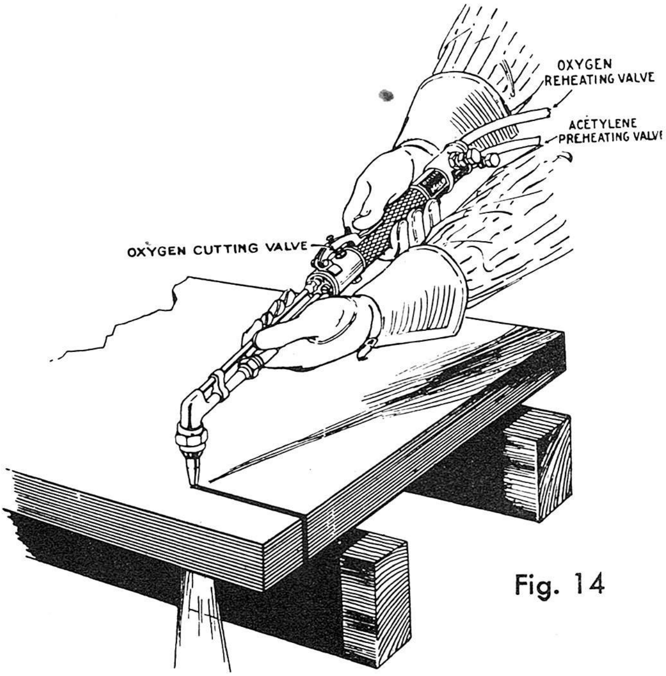

OXYGEN
REHEATING VALVE
ACETYLENE
PREHEATING VALVE
OXYGEN CUTTING VALVE

Fig. 14

DRILLS
Banner Mach. Tool & Supply Co., St. Louis 7, Mo.
Cleveland Twist Drill Co., Cleveland, Ohio
National Twist Drill Co., Detroit, Mich.
Standard Tool Co., Cleveland, Ohio

DRILL GRINDERS
Edw. Blake Co., Newton Centre, Mass.

DRILLING HEADS
Atlas Press Co., Kalamazoo, Mich.
Boice Crane Co., Toledo, Ohio
J. F. Buhr Mach. Tool, Ann Arbor, Mich.
Dorman Machine Works, New York, N. Y.
Errington Mach. Lab., Staten Island, N. Y.
Linderme Mach. & Tool Co., Detroit, Mich.
Reed-Prentice Corp., Worcester, Mass.
B. M. Root Co., York, Pa.

DRILLS, Portable and Hand
Albertson & Co., Sioux City, Iowa
Aro Equipment Corp., Bryan, Ohio
Black & Decker Co., Towson, Md.
Buckeye Tools Corp., Dayton, Ohio
Chicago Pneu. Tool Co., New York, N. Y.
Cincinnati Elec. Tool Co., Cincinnati, O.
Dumore Company, Racine, Wis.
Gaston Power Tools, Evergreen Pk., Ill.
Independent Pneu. Tool Co., Chicago, Ill.
Keller Tool Co., Grand Haven, Mich.
K. O. Lee & Son, Aberdeen, S. D.
Millers Falls Co., Greenfield, Mass.
The Rotor Tool Co., Cleveland 12, Ohio
Skilsaw, Inc., Chicago, Ill.
Speed Way Mfg. Co., Cicero 50, Ill.
Stanley Works, New Britain, Conn.
U. S. Elec. Tool Co., Cincinnati, Ohio
United States Steel Supply Co., Chicago 4, Ill.
United States Steel Corp. Subsidiary
Wodack Elec. Tool Corp., Chicago, Ill.

DRILLS, Radial
Amer. Tool Works, Cincinnati, Ohio

DRILLS, Single and Multiple
Atlas Press Co., Kalamazoo, Mich.
Avey Drilling Mach. Co., Cincinnati, O.
Barnes Drill Co., Rockford, Ill.
Boice-Crane Co., Toledo, Ohio
Buffalo Forge Co., Buffalo, N. Y.
Canedy-Otto Mfg. Co., Chicago Hts., Ill.
Cincinnati Bickford Co., Cincinnati, Ohio
Foote-Burt Co., Cleveland, Ohio
Hamilton Tool Co., Hamilton, Ohio
Leland-Gifford Co., Worcester, Mass.
★McDonald Machinery Co., St. Louis, Mo. (See Adv. under Lathes)
Production Mach. Co., Greenfield, Mass.
B. M. Root Co., York, Pa.
Sellew Mach. Tool Co., Pawtucket, R. I.
Walker-Turner Co., Plainfield, N. J.

DRILL ROD
United States Steel Supply Co., Chicago 4, Ill.
United States Steel Corp. Subsidiary

DRIVES, Machine Tool
Berkeley Equipment Co., Corry, Pa.
Cullman Wheel Co., Chicago, Ill.
Drive-All Mfg. Co., Detroit, Mich.
Given Machy. Co., Los Angeles, Calif.
Lima Elec. Motor Co., Lima, Ohio
Reeves Pulley Co., Columbus, Ohio
Remco Prod. Corp., York, Pa.
Smith Power Transmis'n, Cleveland, O.
Steege Elec. & Machy. Co., Chicago, Ill.
Torq Elec. Mfg. Co., Cleveland, Ohio
Turner Uni-Drive Co., Kansas City, Mo.

DUST COLLECTORS
Acme Tool Co., New York, N. Y.
Aget-Detroit Co., Detroit, Mich.
American Air Filter Co., Louisville, Ky.
C. F. Berg & Co., Boston, Mass.
Covel Mfg. Co., Benton Harbor, Mich
Kirk & Blum, Cincinnati, Ohio
Leiman Bros., Inc., Newark 5, N. J.
Torit Mfg. Co., St. Paul, Minn.

ENGINEERS, Mechanical
Hankins & Trapnell, Richmond, Va.

ENGRAVING MACHINES

AUTO ENGRAVER CO.
Ridgefield, Conn.
Two and three dimensional Pantograph Engraving Machines. Bench and Portable Models Tracer controlled contour milling and profiling machines.
Brewster-Squires Co., New York, N. Y.
Dremel Mfg. Co., Racine, Wis.
Preis Engraving Mach. Co., Newark, N. J.

EXHAUST, Fans
Robbins & Myers, Inc., Springfield, Ohio
Schwitzer-Cummins Co., Indianapolis, Ind.

FACERS, Spot
The Gairing Tool Co., Detroit 32, Mich.
Genesee Mfg. Co., Inc., Rochester, N. Y.
Midwest Tool & Mfg. Co., Detroit, Mich.
Putnam Tool Co., Detroit, Mich.

FANS, Air Circulators

BALDOR ELECTRIC CO.
Saint Louis 10, Mo.
Electrical Specialists Since 1920

FANS
Baldor Elec. Co., St. Louis, Mo.
Robbins & Myers, Inc., Springfield, Ohio

FANS, Exhaust
Robbins & Myers, Inc., Springfield, Ohio
Schwitzer-Cummins Co., Indianapolis, Ind.

FILES, Hand
American Swiss File & Tool Co., Elizabeth 1, N. J.
E. C. Atkins Co., Indianapolis, Ind.
Banner Machine & Tool Co., St. Louis, Mo.
Delta File Co., Philadelphia, Pa.
Henry Disston & Sons, Inc., Philadelphia 35, Pa.
Nicholson File Co., Providence, R. I.
Fayette R. Plumb, Inc., Philadelphia, Pa.
Severance Tool Mfg. Co., Saginaw, Mich.
Simonds Saw & Steel Co., Fitchburg, Mass.

FILES, Rotary
Delta File Co., Philadelphia, Pa.
Henry Disston & Sons, Inc., Philadelphia 35, Pa.
Graham Rotary File & Tool Corp., Philadelphia, Pa
Grobet File Co., New York, N. Y.
Hamilton Tool Co., Hamilton, Ohio
Chas. L. Jarvis Co., Middletown, Conn.
Fayette R. Plumb, Inc., Philadelphia, Pa.
Pratt & Whitney, West Hartford, Conn.
Severance Tool Co., Saginaw, Mich.
N. A. Strand & Co., Chicago, Ill.

CUTTING CAST IRON

Cast Iron Cutting is rapidly taking it's position in industry and daily directly saves many dollars and hours of time. It is now universally recognized as practical and the following brief outline will serve to acquaint the unskilled operator with the fundamental points to follow

APPLICATION

The application of cast iron cutting, while comparatively new, has already spread itself over so broad a field that it requires too much space to describe it thoroughly. However it is fair to say that it follows the cutting of steel in general with it's principle virtues of speed and portability. It has been particularly effective in the cutting up of heavy cast iron scrap, such as heavy flywheels, etc., which unless reduced to convenient size would be worthless and very inconvenient to handle. Considerable saving is produced as the process can be applied where a great many other methods are impossible. Removal of large gears and pulleys from shafts is also a very common use. It also lends itself admirably in the preparation of large cast iron welds in the welding shop.

COST

The cost of cast iron cutting as compared with that of steel, is considerably more, due of course, to the nature of material cut. It is much slower and naturally more gas is consumed per unit of cut, however, this does not limit it's application since it still offers the cheapest and quickest possible method in a great many instances.

EQUIPMENT

Cast Iron Cutting like a great many other valuable processes was slow to gain popularity on account of certain drawbacks. These drawbacks in the main consisted of two, about equally divided, namely, a general lack of knowledge of the art and a suitable torch. Today there are a great many skilled operators as well as a number of efficient torches which have the necessary pep or capacity so necessary for this work.

CUTTING DEPENDS ON COMPOSITION OF CAST IRON

To intelligently describe this process, we must first consider the nature of cast iron from two angles. Since it has such a wide range of use, it is natural that we may expect a wide difference in quality or chemical composition and a corresponding difference in ease of cutting. The better grades of castings such as are machined are more easily cut and those made of random grades of scrap such as counterweights, gratebars, floorplates, etc., present greater difficulty, requiring more gas, a wider kerf, and a corresponding slower rate of cutting speed. Different thickness is also a factor which will be considered later under heading of instructions.

PREPARATION

There is a rule for heavy steel cutting, which certainly applies in every way to cast iron cutting and that is DO NOT START THE CUT UNTIL YOU ARE CERTAIN THAT YOU CAN COMPLETE IT. It is obvious that if the cut is stopped on a heavy section, that it is extremely difficult to start it again and may doubly increase the cost as well as the annoyance. Considerable more heat as well as sparks and slag are generated in cast iron so that proper protection to the body, face, and limbs is necessary. Asbestos gloves are essential and a fire brick or suitable torch rest is desirable.

FILING MACHINES

All American Tool & Mfg. Co., Chicago 14, Ill.
Armglo Company, Milwaukee, Wis.
Continental Mach., Inc., Minneapolis
H. & H. Research Co., Detroit, Mich.
Keller Tool Co., Grand Haven, Mich.
Postel Filing Mach. Co., Minneapolis

FILTERS, Air

Aget-Detroit Co., Detroit, Mich.
American Air Filter Co., Louisville, Ky.
M-B Products, Detroit, Mich.
C. A. Norgren Co., Denver, Colo.
Sterling Tool Prod. Co., Chicago, Ill.

FIRST AID

E. D. Bullard Company, San Francisco, Calif.

FLATING, STAMPING & FIRST OPERATIONS BLANKS

The Ohio Nut & Washer Co.
Mingo Junction, Ohio

FLEXIBLE SHAFT EQUIPMENT

Acme Tool Co., New York, N. Y.
Dumore Co., Racine, Wis.
Foredom Elec. Co., New York, N. Y.
R. G. Haskins Co., Chicago, Ill.
Pratt & Whitney, West Hartford, Conn.
Stow Mfg. Co., Binghamton, N. Y.
White Dental Mfg. Co., New York, N. Y.
Wyzenbeek & Staff, Chicago, Ill.

FORGES

Buffalo Forge Co., Buffalo, N. Y.
Diamond Iron Works, Minneapolis, Minn.
Johnson Gas Appl. Co., Cedar Rapids, Ia.

FURNACES, Heat Treating

Amer. Elec. Furnace Co., Boston, Mass.
Amer. Gas Furnace Co., Elizabeth, N. J.
Bennett Ins. Steel Trtg. Co., Newark, N. J.
Delaware Tool Steel Corp., Wilmington 99, Delaware
Despatch Oven Co., Minneapolis, Minn.
Electric Furnace Co., Salem, Ohio
Hevi Duty Elec. Co., Milwaukee, Wis.
Stark Tool Co., Waltham, Mass.
Thermo Electric Mfg. Co., Dubuque, Iowa
Upton Elec. Furn. Co., Detroit, Mich.

GAGES, Indicating

Dearborn Gage Co., Dearborn, Mich.
Federal Products Corp., Providence 1, R. I.
Guedon Co., Audubon, N. J.
Liberty Tool & Gage Wks., Providence
Lufkin Rule Co., Saginaw, Mich.
Marshalltown Mfg. Co., Marshalltown, Ia.
★Modern Engineering Co., St. Louis, Mo. (See Adv. Back Cover)
Montgomery Engineering Co., Detroit 4, Mich.
J. R. Reich Mfg. Co., Dayton, Ohio
Geo. Scherr Co., New York, N. Y.
Sheffield Gage Corp., Dayton, Ohio
Standard Gage Co., Poughkeepsie, N. Y.
The L. S. Starrett Co., Athol, Mass.
Swedish Gage Co., Detroit 4, Mich.
United Precision Prod. Co., Chicago, Ill.

GAGE BLOCKS

C. E. Johansson Gage Co., Detroit 4, Mich.

GEARS

Abart Gear & Mach. Co., Cicero, Ill.
Boston Gear Works, No. Quincy, Mass.
Brewer Machine & Mfg. Co., St. Louis, Mo.
Chicago Gear Works, Chicago, Ill.
Fellows Gear Shaper Co., Springfield, Vt.
Gleason Works, Rochester, N. Y.
Greaves Mach. Tool Co., Cincinnati, Ohio
Ohio Gear Co., Cleveland, Ohio
Phila. Gear Works, Philadelphia, Pa.

GEAR CUTTING

Brewer Machine & Mfg. Co., St. Louis, Mo.

GEAR CUTTING MACHINERY

Barber-Colman Co., Rockford, Ill.
Fellows Gear Shaper Co., Springfield, Vt.
Gleason Works, Rochester, N. Y.
Hamilton Tool Co., Hamilton, Ohio
Michigan Tool Co., Detroit, Mich.

GEAR GUARDS

Littleford Bros. Inc., Cincinnati 2, Ohio

GENERAL MACHINE WORK

Brewer Machine & Mfg. Co., St. Louis, Mo.

GOGGLES, Safety

E. D. Bullard Company, San Francisco, Calif.

GOUGES

Winsted Edge Tool Works, Winsted, Conn.

GRINDERS, Ball Bearing

GRINDERS, Bench and Stand

Armglo Company, Milwaukee, Wis.
Atlas Press Co., Kalamazoo, Mich.
Baldor Electric Co., St. Louis, Mo.
Brown-Brockmeyer Co., Dayton, Ohio
Cincinnati Machy. & Sup. Co., Cincinnati
Clizbe Bros. Mfg. Co., Plymouth, Ind.
Cutter Machine Co., St. Louis, Mo.
Grenby Mfg. Co., Plainville, Conn.
Hammond Mchy. Bldrs., Kalamazoo, Mich.
Hisey-Wolf Mach. Co., Cincinnati, Ohio
LaSalle Tool Co., Ottawa, Ill.
K. O. Lee & Son, Aberdeen, S. D.
The Lima Electric Motor Co., Lima, Ohio
Keystone Grinder & Mfg. Co., Pittsburgh 19, Pa.
M-B Products, Detroit, Mich.
Millers Falls Co., Greenfield, Mass.

Continued on next page

PRESSURE TABLE

Type L. Standard Cutting Torch

Size of Tip	Thickness Metal	Oxygen Pressure	Acetylene Pressure
L-3CH	½″ ¾″ 1″ 1½″ 2″	40 lbs. 45 lbs. 50 lbs. 60 lbs. 70 lbs.	7 to 8 lbs.
L-4CH	3″ 4″ 6″ 8 10 12	80 lbs. 90 lbs. 110 lbs. 120 lbs. 150 lbs. 170 lbs.	8 to 10 lbs.

CUTTING HINTS

For cutting the better grades of cast iron or grey iron, set the regulators to deliver the proper pressure as indicated on the pressure table. The regulator adjustment of course is made with the high pressure cutting valve open to allow for the customary drop.

Next light the torch and adjust the preheating flame so that it will show an excess of acetylene. This is preferably done with the high pressure valve wide open to avoid any change in the character of the flame during the actual cutting operation. This is important. The excess of acetylene as indicated by the length of the white cone must be varied to best suit the grade and thickness of the material cut. Experience is naturally the best guide on this point, however, it will generally vary from little or no excess of acetylene for the extremely light sections to an excess as indicated by a white cone of a length of one to two inches for the heavier sections cut.

Due to the higher cost of cast iron cutting it is well to plan the work carefully; first to avoid any unnecessary cuts, and also take advantage of all helpful hints. As the cutting of cast iron requires a higher ignition temperature, some gas can be saved by preheating the heavier sections along the line of the start of the cut.

BRASS AND BRONZE

Brasses and bronzes are composed of copper, with lower melting metals as alloys, zinc, tin, etc. Since these metals have different melting points, considerable care must be exercised in welding not to change the character of the metal too much by burning out these alloys.

The metal should be prepared the same as any other, with particular care in setting up to prevent collapse of the heated area. The metal should not be brought to fusion by bringing the cone in contact with it, but as with copper, the end of the cone should be slightly above the metal. For repair purposes, Tobin Bronze or Manganese Bronze should be used for the welding rod—for foundries or in manufacturing where the weld must be practically the same color and the same material as the metal, more judgment is necessary in the choice of the rod, with a view of replacing by means of the material in the welding rod those metals burnt out of the line of welding by the flame.

GRINDERS, Bench and Stand
Standard Elec. Tool Co., Cincinnati, O.
Rivett Lathe & Grinder Co., Boston, Mass.
T. C. M. Mfg. Co., Harrison, N. J.
Valley Electric Corp., St. Louis, Mo.
Vonnegut Moulder Co., Indianapolis, Ind.
Walls Sales Corp., New York, N. Y.

GRINDERS, Bench Pneumatic
United States Steel Supply Co., Chicago 4, Ill.
United States Steel Corp. Subsidiary

GRINDERS, Carbide
Baldor Electric Co., St. Louis, Mo.
Willeys Carbide Tool Co., Detroit, Mich.

GRINDERS, Cutter and Tool
Cincinnati Grinders, Inc., Cincinnati, Ohio
Cleveland Tool & Eng. Co., Cleveland, O.
Cutter Machine Co., St. Louis, Mo.
Gallmeyer & Livingston, Grand Rapids
Grenby Mfg. Co., Plainville, Conn.
LeBlond Mach. Tool Co., Cincinnati, Ohio
K. O. Lee & Son, Aberdeen, S. D.
McDonough Mfg. Co., Eau Claire, Wis.
Mico Instrument Co., Cambridge 38, Mass.

GRINDERS, Drill
Black Diamond Saw Mach., Natick, Mass.
Edw. Blake Co., Newton Centre, Mass.
Galland-Henning Mfg. Co., Milwaukee, Wis.
Keystone Grinder & Mfg. Co., Pittsburgh 19, Pa.
Kokomo Mach. Co., Kokomo, Ind.
McDonough Mfg. Co., Eau Claire, Wis.
Montgomery Engineering Co., Detroit Mich.
Standard Elec. Tool Co., Cincinnati, O.
Star Elec. Motor Co., Bloomfield, N. J.
Washburn Shops, Worchester 2, Mass.

GRINDERS, Portable, Air
Aro Equipment Corp., Bryan, Ohio
Buckeye Tools Corp., Dayton, Ohio
Chicago Pneu. Tool Co., New York, N. Y.
Independent Pneu. Tool Co., Chicago, Ill.
Ingersoll-Rand Co., New York, N. Y.
Keller Tool Co., Grand Haven, Mich.
M-B Products Co., Detroit, Mich.
Onsrud Mach. Works, Chicago, Ill.
The Rotor Tool Co., Cleveland 12, Ohio

GRINDERS, Portable, Electric
Baldor Elec. Co., St. Louis, Mo.
Chicago Pneu. Tool Co., New York, N. Y.
Chicago Wheel & Mfg. Co., Chicago, Ill.
Cincinnati Elec. Tool Co., Cincinnati, Ohio
H. & H. Research Co., Detroit, Mich.
Chas. L. Jarvis Co., Middletown, Conn.
K. O. Lee & Son, Aberdeen, S. D.
Skilsaw Inc., Chicago, Ill.
Speed Way Mfg. Co., Cicero 50, Ill.
Standard Elec. Tool Co., Cincinnati, O.
Stanley Works, New Britain, Conn.
S. S. White Dental Co., New York, N. Y.

GRINDERS, Portable Pneumatic
Jefferson Mach. Tool Co., Cincinnati, O.

GRINDERS, Snagging
Cutter Machine Co., St. Louis, Mo.
Standard Elec. Tool Co., Cincinnati, O.
Vonnegut Moulder Corp., Indianapolis 2, Ind.

GRINDERS, Surface (Hydraulic Feed)
Gallmeyer & Livingston Co., Grand Rapids, Mich.
Standard Elec. Tool Co., Cincinnati, O.

GRINDERS, Swing Frame
Jefferson Mach. Tool Co., Cincinnati, O.
Vonnegut Moulder Corp., Indianapolis 2, Ind.

GRINDERS, Tap
Gallmeyer & Livingston Co., Grand Rapids, Mich.

GRINDERS, Universal & Tool
Gallmeyer & Livingston Co., Grand Rapids, Mich.

GRINDING WHEELS
Abrasive Co., Philadelphia, Pa.
Amer. Emery Wheel Co., Providence, R. I.
Atlantic Abrasive Co., So. Braintree, Mass.
Bay State Abrasive Prod., Westboro, Mass.
Bridgeport Safety Em. Wheel, Bridgeport
Carborundum Co., Niagara Falls, N. Y.

GUARDS, Power Presses
Searjeant Metal Products, Inc., Mendon, N. Y.

HACK SAW FRAMES
Clemson Bros., Inc., Middletown, N. Y.
Forsberg Mfg. Co., Bridgeport, Conn.
Napier Saw Works, Middletown, N. Y.
Simonds Saw & Steel Co., Fitchburg, Mass.
Victor Saw Works, Middletown, N. Y.

HACK SAW MACHINES
Clemson Bros., Inc., Middletown, N. Y.
Cove Hanchett Co., Portland, Ore.
Forsberg Mfg. Co., Bridgeport, Conn.
Napier Saw Works, Middletown, N. Y.
Simonds Saw & Steel Co., Fitchburg, Mass.
Racine Tool & Mach. Co., Racine, Wis.
Rapid Mfg. Co., Glendale, Calif.
Sales Service Machine Tool Co., Saint Paul W4, Minn.
Victor Saw Works, Middletown, N. Y.

HAMMERS, Air
The Rotor Tool Co., Cleveland 12, Ohio

HAMMERS, Electric
Chicago Pneu. Tool Co., New York, N. Y.
Independent Pneu. Tool Co., Chicago, Ill.
Wodack Elec. Tool Corp., Chicago, Ill.

HAMMERS, Soft
Chicago Rawhide Mfg. Co., Chicago, Ill.
Greene-Tweed & Co., New York, N. Y.
P & C Hand Forged Tool Co., Portland 22, Oregon
Stanley Works, New Britain, Conn.

HAULING, General

HELMETS
Mine Safety Appliances Co., Pittsburgh, Pa.

containing considerable slag will require a greater oxygen pressure than new or clear metal. A safe rule to follow is that the Oxygen pressure must always be high enough to make the Oxygen burn entirely through. To light the torch for cutting, first open the Acetylene preheating valve, and light it as if for welding. Have a clear space between the burning gas and the tip of one-thirty-second to one-eighth inch, then turn on the oxygen preheating valve until the neutral flame is attained. Now open the Oxygen cutting valve controlling the high pressure oxygen jet, and observe the preheating flame. If it draws long and becomes carbonizing, open the Oxygen preheating valve more, until the preheating flame remains neutral. We are now ready to begin cutting. First be sure there is a clear space underneath the line of the cut for the slag to run free of the metal.

GENERAL ARC WELDING DATA FOR WELDING MILD STEEL SHEETS

Thickness	Electrode Recommended	Approximate Current	Spacing and Beveling
22 ga.	1/16" coated	25 to 35 amperes	1/32" between edges
20 ga.	1/16" coated	30 to 40 amperes	1/32" between edges
18 ga.	3/32" bare or coated	60 to 75 amperes	3/64" between edges
16 ga.	3/32" bare or coated	65 to 80 amperes	1/16" between edges
14 ga.	1/8" bare or coated	70 to 85 amperes	1/16" between edges
12 ga.	1/8" bare or coated	85 to 95 amperes	5/64" between edges
1/8"	1/8" bare or coated	90 to 100 amperes	1/8" between edges
5/32"	5/32" bare or coated	110 to 125 amperes	5/32" between edges
3/16"	5/32" bare or coated	120 to 140 amperes	3/16" between edges
3/16"	3/16" bare or coated	140 to 165 amperes	3/16" between edges
1/4"	3/16" bare or coated	150 to 175 amperes	Single "V"—90 degrees
5/16"	3/16" bare or coated	150 to 175 amperes	Single "V"—90 degrees
3/8"	1/4" coated	175 to 225 amperes	Either single or double
1/2"	1/4" coated	180 to 235 amperes	"V"—90 degrees (double
5/8"	1/4" coated	200 to 250 amperes	preferred if possible).

NOTE—The above data applies to general practice for average requirements in welding together mild steel sheets of equal thickness. Under special requirements, expert operators may deviate from these values for greater speed. When sheets of unequal thickness are to be welded together, use data applying approximately to a size about half way between the two but apply the welding arc mostly to the thicker of the two sheets. Size of electrode should favor the thinner sheet if there is no data for a thickness midway between the two.

HINGES
Auto Moulding & Mfg. Co., Chicago, Ill.
S and S Machine Wks., Chicago, Ill.

HOBBING MACHINES
Brown & Sharpe Mfg., Providence, R. I.
Gould & Eberhardt, Irvington, N. J.
The Hamilton Tool Co., Hamilton, Ohio
Lees-Bradner Co., Cleveland, Ohio

HOISTS
Amer. Engineering Co., Philadelphia, Pa.
Chisholm Moore Hoist Corp., Tonawanda
Coffing Hoist Co., Danville, Ill.
Detroit Hoist & Mach. Co., Detroit, Mich.
Grand Specialties Co., Chicago 22, Ill.
Harnischfeger Corp., Milwaukee, Wis.
Keller Tool Co., Grand Haven, Mich.
The Reading Machine Co., Reading, Ohio
Robbins & Myers, Inc., Springfield, Ohio
Shaw Box Crane & Hoist, Muskegon, Mich.

HOSE, Metallic
Chicago Metal Hose Corp., Maywood, Ill.
Titeflex Metal Hose Co., Newark, N. J.
Weatherhead Co., Cleveland, Ohio

JIGS AND FIXTURES
Richards' Industries, Inc., Grand Rapids 5, Mich.

KEYSEATERS
Amer. Broach & Mach., Ann Arbor, Mich.
Brewer Machine & Mfg. Co., St. Louis, Mo.
John T. Burr Co., Brooklyn, N. Y.
The du Mont Corp., Greenfield, Mass.
Morton Mfg. Co., Muskegon Heights, Mich.
The Reading Machine Co., Reading, Ohio

KEYWAY BROACHES
East Shore Machine Products Co., Cleveland, Ohio

KNIFE GRINDERS AND HONERS
Covel-Hanchett Co., Big Rapids, Mich.
Micromatic Hone Corp., Detroit, Mich.
S. C. Rogers & Son Co., Philadelphia, Pa.
Sunnen Prod. Co., St. Louis, Mo.

KNURLING TOOLS
Armstrong Bros. Tool Co., Chicago, Ill.
Graham Mfg. Co., Providence, R. I.
Reed Roller Thread Die Co., Worchester 2, Mass.
Wade Tool Co., Waltham, Mass.

LAPPING MACHINES, Precision
Crane Packing Co., Chicago 13, Ill.

LATHES, Automatic
Cone Automatic Mach. Co., Windsor, Vt.
Gisholt Machine Co., Madison 10, Wis.
Jones & Lamson Mach., Springfield, Vt.
LeBlond Mach. Tool Co., Cincinnati, Ohio
Monarch Mach. Tool Co., Sidney, Ohio
Seneca Falls Mach. Co., Seneca Falls, N. Y.
Sundstrand Mach. Tool Co., Rockford, Ill.

LATHES, Bench
B. C. Ames Co., Waltham, Mass.
Atlas Press Co., Kalamazoo, Mich.
Elgin Tool Works, Chicago, Ill.
Hardinge Bros. Inc., Elmira, N. Y.
McDonald Machinery Co., St. Louis, Mo.
Rivett Lathe & Grinder Co., Boston, Mass.
Sloan & Chace Mfg. Co., Kearney, N. J.
South Bend Lathe Wks., South Bend, Ind.
Stark Tool Co., Waltham, Mass.

LATHE CENTERS
Pratt & Whitney, West Hartford, Conn.

LATHES, Engine
Amer. Tool Works, Cincinnati, Ohio
Bradford Mach. Tool Co., Cincinnati, Ohio
LeBlond Mach. Tool Co., Cincinnati, Ohio
Lehman Mach. Co., St. Louis, Mo.
McDonald Machinery Co., St. Louis, Mo.
Monarch Mach. Tool Co., Sidney, Ohio
Porter-McLeod Mach. Co., Hatfield, Mass.
Reed-Prentice Corp., Worcester, Mass.
The Sidney Machine Tool Co., Sidney, O.
Simmons Mach. Tool Corp., Albany, N. Y.
South Bend Lathe Wks., South Bend, Ind.

LATHES, Sebastian
King Machine Tool Div. of American Steel Foundries, Cincinnati 29, Ohio
Sebastian Lathe Co., Cincinnati, Ohio

LATHES, Spinning, Polishing, Etc.
Atlas Press Co., Kalamazoo, Mich.
Boice-Crane Co., Toledo, Ohio
Clizbe Bros., Plymouth, Ind.
Jefferson Mach. Tool Co., Cincinnati, O.
W. C. Lipe. Inc., Syracuse, N. Y.
Standard Elec. Tool Co., Cincinnati, O.
Walker-Turner, Inc., Plainfield, N. J.

LATHES, Toolroom
Amer. Tool Works, Cincinnati, Ohio
Atlas Press Co., Kalamazoo, Mich.
The Boye & Emmes Machine Tool Co., Cincinnati 15, Ohio
Gisholt Machine Co., Madison 10, Wis.
Hardinge Bros., Inc., Elmira, N. Y.
LeBlond Mach. Tool Co., Cincinnati, Ohio
McDonald Machinery Co., St. Louis, Mo.
Reed-Prentice Corp., Worcester, Mass.
Rivett Lathe & Grinder Co., Boston, Mass.
The Sidney Machine Tool Co., Sidney, O
South Bend Lathe Wks., South Bend, Ind.

LATHES, Turret
The Bullard Co., Bridgeport, Conn.
Douglas Mchy. Co., New York, N. Y.
Ganey Machinery Co., Buffalo, N. Y.
Gisholt Machine Co., Madison 10, Wis.
Jones & Lamson Mach., Springfield, Vt.
Morey Machinery Co., New York, N. Y.
National Acme Co., Cleveland, Ohio
Potter & Johnston Co., Pawtucket, R. I.
Rivett Lathe & Grinder Co., Boston, Mass.
Sebastian Lathe Co., Cincinnati, Ohio
Warner & Swasey Co., Cleveland, Ohio

LIGHTING FIXTURES
Hygrade Sylvania Corp., Salem, Mass.

LOCK NUTS
Columbia Nut and Bolt Co., Bridgeport, Conn.

LUBRICATING SYSTEMS
Alemite Co., Chicago, Ill.
Bijur Lubricating Corp., L. I. City, N. Y.
M-B Products Co., Detroit, Mich.
Madison-Kipp Corp., Madison, Wis.
C. A. Norgren Co., Denver, Colo.
Rivett Lathe & Grinder Co., Boston, Mass.
Trico Fuse Co., Milwaukee, Wis.

LUBRICATORS, Automatic Air Line
M-B Products Co., Detroit, Mich.

MACHINERY, Moving.

ARTHUR MORGAN TRUCKING CO.
2923 N. Broadway, St. Louis, Mo.

ARC WELDING DATA

LENGTH OF FILLET WELD TO REPLACE RIVETS

Rivet Dia. Size	Rivet Shear Value at 12,000 lbs. per sq. in.	Length of Fillet Welds (to nearest 1/8 in.) "Fusion Code" (Structural) Shielded Arc Welding				
		¼ in. Fillet	5/16 in. Fillet	⅜ in. Fillet	½ in Fillet	⅝ in. Fillet
½"	2356	1¼"	1 "	1 5/16"	¾"	11/16"
⅝"	3682	1¾"	1½"	1¼"	1 "	⅞"
¾"	5301	2½"	2 "	1¾"	1⅜"	1⅛"
⅞"	7216	3¼"	2¼"	2¼"	1¾"	1½"
1"	9425	4¼"	3⅜"	3 "	2¼"	1⅞"

Note: ¼" is added to calculated length of fillet.

SAFE ALLOWABLE LOADS FOR FILLET WELDS IN SHEAR

Size of Fillet Weld	Pounds per Lineal Inch—"Fusion Code" (Structural)—A.W.S.
⅛"	1200
3/16"	1800
¼"	2400
5/16"	3000
⅜"	3600
½"	4800
⅝"	6000
¾"	7200

PROPERTIES OF SHIELDED ARC WELD METAL AND MILD ROLLED STEEL

Material	Tensile Strength Lbs./sq. in.	% Elongation in 2 inches	Density Grams Per c.c.	Endurance Limit* Lbs./sq. in.	Notched Bar Ft. Lbs.
Weld Metal, made with shielded arc	65,000-75,000	20-35	7.84-7.86	28,000-32,000	25-80 (Izod)
Mild Rolled Steel	55,000-65,000	20-30	7.86	24,000-28,000	20-80 (Izod)

* Maximum stress in outside fibres, 10 million reversals without failure. Rotating beam test.

STRENGTH OF WELDED JOINTS: Calculation of the designed strength of any welded joint should include consideration of the following factors:

(1) Strength of weld metal.
(2) Type of weld.
(3) Location of weld in relation to parts joined.

In calculating the strength of fillet welds, a unit stress of 13,600 lbs. per square inch is usually employed for tension, shear and compression since in practically every fillet weld shear is present.

For dynamic, vibrational or lifting loads, the unit stress of fillet welds or the strength per lineal inch, should be reduced, depending upon the severity of the load.

Approximately ¼ in. should be added to the designed length of fillet welds for starting and stopping the arc. The crater in the welds should be filled.

The working strength of butt welds, of 100 per cent penetration into the base metal, is usually calculated by multiplying the net cross sectional area through the throat of the weld by 15,600 lbs. for tension—by 13,600 lbs. for shear—by 18,000 lbs. for compression.

The location of the weld in relation to the parts joined, in many cases, has an effect on the strength of the welded joint. As an example, repeated tests reveal that, when other factors are equal, welds having their linear dimension transverse to the lines of stress are approximately 30 per cent stronger per average unit length than welds with linear dimension parallel to lines of stress. This is depicted graphically in Fig. 1 and is due to the stress distribution along the bead.

(Continued)

MACHINERY BUSHINGS
The Ohio Nut & Washer Co.
Mingo Junction, Ohio

MACHINERY, New and Used
Ariz. Machinery Co., Phoenix, Ariz.
McDonald Machinery Co., St. Louis, Mo.
Southern Machinery Corp., Lakeland, Fla.

MANDRELS (See ARBORS AND MANDRELS)
K. O. Lee & Son, Aberdeen, S. D.

MARKERS, Wire, Pipe and Conduit
W. H. Brady Company, Milwaukee, Wis.

MARKING & NUMBERING MACHINES
Acromark Corporation, Elizabeth, N. J.
W. H. Brady Company, Milwaukee, Wis.
Durant Mfg. Co., Milwaukee, Wis.
New Method Steel Stamp, Detroit, Mich.

Numberall Stamp & Tool Co., Inc.
379 Huguenot Ave., Hugenot Pk., S.I., N.Y.
Single and Multiple Wheel Numbering Stamps and Machines. Automatic Numbering Machines. Name Plate Detail Presses and Platforms. Stamp Holders and Marking Apparatus.

The Pannier Corp., Pannier Bldg., Pittsburgh, Pa.

SUPERIOR SEAL & STAMP CO.
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MASKS, Sandblasting, Tumbling, Plating
W. H. Brady Company, Milwaukee, Wis.

METAL NAME PLATES
The C. H. Hanson Co., Chicago 10, Ill.

METERS
Brown Instrument Co., Philadelphia, Pa.

MICROMETERS
Banner Mach. Tool & Supply Co., St. Louis 7, Mo.
Brown & Sharpe Mfg., Providence, R. I.
Federal Products Corp., Providence 1, R. I.
Lufkin Rule Co., Saginaw, Mich.
Micro Products Co., Detroit, Mich.
Millers Falls Co., Greenfield, Mass.
The L. S. Starrett Co., Athol, Mass.

MILLING ATTACHMENTS
Blank & Buxton Machy., Jackson, Mich.
Burke Mach. Tool Co., Conneaut, Ohio
Halco Products Co., Detroit, Mich.
Jefferson Mach. Tool Co., Cincinnati, Ohio
Kearney & Trecker Corp., Milwaukee, Wis.
Liberty Tool & Gage Wks., Providence
Precision Tool Co., Brooklyn, N. Y.

MILLING CUTTERS
Lovejoy Tool Co., Inc., Springfield, Vt.

MILLING MACHINES
Atlas Press Co., Kalamazoo, Mich.
Bridgeport Machines, Inc., Bridgeport
Brown & Sharpe Mfg. Co., Providence
Cincinnati Mill. Mach. Co., Cincinnati, O.
Cincinnati Planer Co., Cincinnati, Ohio
Douglas Machinery Co., New York, N. Y.
Ekstrom, Carlson Co., Rockford, Ill.
Ingersoll Mill. Mach. Co., Rockford, Ill.
Jackson Mach. & Tool Co., Jackson, Mich.
Jefferson Mach. Tool Co., Cincinnati, O.
Kearney & Trecker Corp., Milwaukee, Wis.
Morton Mfg. Co., Muskegon Heights, Mich.
Nichols-Morris Corp., 50 Church Street, New York 7, N. Y.
Reed-Prentice Co., Worcester, Mass.
Sundstrand Machine Tool Co., Rockford, Ill
Van Norman Mch. Tool, Springfield, Mass.

MILLING MACHINES, Bench & Hand
Burke Mach. Tool Co., Conneaut, Ohio
Elgin Tool Works, Chicago, Ill.
Jefferson Mach. Tool Co., Cincinnati, O.
Kent-Owens Mach. Co., Toledo, Ohio
Nichols-Morris Corp., 50 Church Street, New York 7, N. Y.
Palmer Industries, Chicago 21, Ill.
Pratt & Whitney, West Hartford, Conn.
Producto Mach. Co., Bridgeport, Conn.

MODELS

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No Casting can be better than the Pattern from which it is made
Quality, Service and Satisfaction

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1810 Elliott Ave., St. Louis, Mo.
FRanklin 6370

Baum's Metal Specialties, Kansas City, Mo.

INVENTIONS PROMOTED
Patented or Unpatented. In business over 30 years. Send drawing and description or model, or write for information. Complete facilities. References.

Adam Fisher Company
621 ENRIGHT, ST. LOUIS, MO.

MOTORS, Electric

BALDOR ELECTRIC COMPANY
Manufacturers Electric Motors
4351-59 Duncan Ave. St. Louis 10, Mo.
Baldor Ball Bearing Grinders ½ H.P., 3400 R.P.M., Wheels 7" x 1" x ⅝" $60.00. A complete line 6" thru 12" ¼ H.P. thru 3 H.P.

BALDOR ELECTRIC CO.
Saint Louis 10, Mo.
Electrical Specialists Since 1920

Gast Mfg. Corp., Benton Harbor, Mich.

THE LELAND ELECTRIC COMPANY
1501 Webster St., Dayton 1, Ohio
HE-0461
Electric motors delivery from stock on ratings from 1/6 to 5 horsepower. Single phase, three phase, direct current; open dripproof, totally enclosed. Sales representatives and dealers in all principal cities.

(Continued)

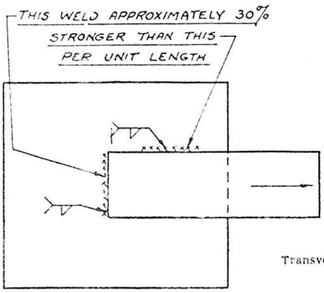

FIG. 1
Transverse welds are stronger than welds parallel to lines of stress.

If the load on the weld is to be properly distributed the welds should be located so as to take account of the shape of the sections joined. An example is illustrated by Fig. 2. The ratio of the lengths of the welds at heel and toe of the angle is such that there will be no tendency for the angle to turn and thus cause eccentric loads on the joint.

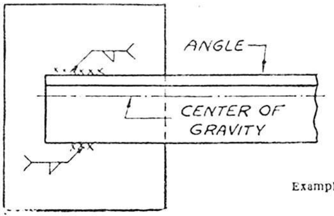

FIG. 2
Example of correct lengths of welds for equal load distribution.

Resistance to a turning effect ot one member at a joint is best obtained by welds well separated rather than by a single weld or welds close together. In Fig. 3 a single weld at A is not as effective as welds at both A and B in resistance to turning effect. Two small welds at A and B are much more effective than a large single weld at A or B only

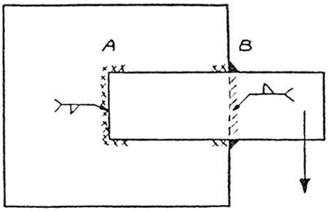

FIG. 3
Example of proper placement of welds to resist turning effect of one member at the joint.

If possible, welded joints should be designed so that bending or prying action is minimized. Symmetrical joints are most desirable as they are very much stronger than non-symmetrical joints, the stress in symmetrical joints being more evenly distributed.

In some designs it may be desirable to take into account the distribution of stress through the welds in a joint. It is known that any abrupt change in surface (for example, a notch or saw cut in a square bar under tension) increases the local stress or causes stress concentration. As an illustration of this principle, the weld, Fig. 4, will have considerably more concentration of stress

(Continued)

MOTORS, Electric

The Lima Electric Motor Co., Lima, Ohio

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Columbia Nut and Bolt Co., Bridgeport, Conn.

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American Pattern & Model Co., St. Louis, Mo.

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Ahlberg Bearing Co., Chicago, Ill.
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Osborn Mfg. Co., Warsaw, Ind.

PRESSES, Arbor

Canedy-Otto Mfg. Co., Chicago Hts., Ill.
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W. H. Nicholson & Co., Wilkesbarre, Pa.

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PRESS GUARDS

Searjeant Metal Products, Inc., Mendon, N Y.

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Dake Engine Co., Grand Haven, Mich.
Elmes Engineering Co., Chicago, Ill.
Hannifin Mfg. Co., Chicago, Ill.
Hydraulic Press Mfg. Co., Mt. Gilead, O.
O. C. Keckley Co., Springfield, Ill.
Logansport Machine Co., Inc., Logansport, Ind
Niagara Machine & Tool Works, Buffalo N. Y.
The Oilgear Co., Milwaukee 4, Wis.
Remco Prod. Corp., York, Pa.
Verson Allsteel Press Co., Chicago. Ill.

PRESSES, Power

Buffalo Forge Co., Buffalo, N. Y.
Excelsior Tool and Machine Co., East St. Louis, Ill.
Federal Press Co., Elkhart, Ind.
L and J Press Corp., Elkhart, Ind.
J. L. Lucas & Son, Bridgeport, Conn.
Milliken Mach. Co., West Newton, Mass.
Niagara Machine & Tool Works, Buffalo 11, N. Y.
A. H. Nilson Mach. Co., Bridgeport, Conn.
Sales Service Machine Tool Co., Saint Paul W4. Minn.
Service Machine Co., Chicago 20, Ill.
Verson Allsteel Press Co., Chicago, Ill.
Zeh & Hahnemann, Newark, N. J.

PRESSURE UNITS

Richards' Industries, Inc., Grand Rapids 5, Mich.

PRINTING

Charles Martin Lithographing Co., St. Louis 3, Mo.

Standard Press, Printing, L. A. McClennan, Prop., Box 381, St. Louis, Mo.

PULLEYS

Banner Machine Tool Co., St. Louis, Mo.
Dodge Mfg. Corp., Mishawauka, Ind.
Link-Belt Co., Chicago, Ill.
Medart Company. St. Louis, Mo.
Rockwood Mfg. Co., Inc., Indianapolis 6, Ind.
Sprout, Waldron & Co., Inc., Muncy, Pa.

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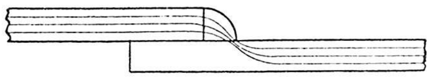

FIG. 4

Example of lap weld having poor distribution of stress through weld.

than that in Fig. 5. Fig. 6 allows a much more uniform transfer of stress with a resulting minimum of stress concentration. In many cases such concentra-

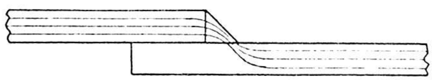

FIG. 5

Example of lap weld having a more even distribution of stress through weld.

tion of stress might be small and of minor consequence. However, in heavy or repeated loadings this matter should have the attention of the designer.

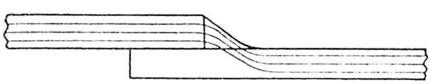

FIG. 6

Example of lap weld in which there is a fairly uniform transfer of stress through the weld.

Stress in a weld having its linear dimension approximately parallel to the line of force is not evenly distributed. Under many load conditions, not at all unusual, the stress is greater at the ends of the weld than in the middle. It is therefore, advisable in certain conditions to hook the bead around the joint as indicated in Fig. 7. When this is done, far greater resistance to a tearing action on the weld is obtained.

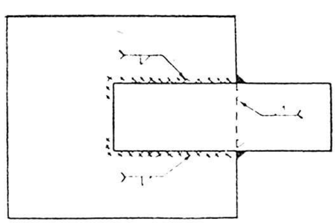

FIG. 7

Example of welds hooked around the corners to obtain resistance to tearing action on welds when subjected to eccentric loads.

These allowable loads are based on a stress of 13,600 lbs. per square inch in throat section as specified in Structural Code of A.W.S. They are conservative, being based on a factor of safety of about 5, since weld metal has 60,000 to 65,000 pounds per square inch ultimate strength.

In many cases it may be exceeded by 20 per cent or more, depending upon the type of load and character of joint. Then, it would still give factor of safety of about 4.

PULLEYS

PUMPS, Coolant, Lubricant, Etc.
Eastern Engineering, New Haven, Conn.
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Logansport Machine Co., Inc., Logansport, Ind
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Ruthman Mchy. Co., Cincinnati, Ohio
Tomkins-Johnson Co., Jackson, Mich.
Vickers Inc., Detroit, Mich.

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E. A. Baumbach Mfg. Co., Chicago, Ill.
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The J. F. Kidder Mfg. Co., Inc., Burlington, Vt.
Lapeer Mfg. Co., Lapeer, Mich.
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Stanley Works, New Britain, Conn.

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Excelsior Tool and Machine Co., East St. Louis, Ill.
Federal Press Co., Elkhart, Ind.
Wiedeman Machine Co., Philadelphia, Pa.

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Gordon L. Hall Co . Old Lyme, Conn.
Pollard Bross Mfg. Co., Chicago, Ill.
Stackbin Corp., Providence, R. I.
Yohe Supply Co., Canton, Ohio
Western Tool & Mfg. Co., Springfield, O.

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Amer. Tool Works, Cincinnati, Ohio

RADIUM PAINTING
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REAMERS
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Hart Machine Co., Dorchester, Mass.
The Rotor Tool Co., Cleveland 12, Ohio
Wendt-Sonis Co., Hannibal, Mo.

RIVETING BURRS
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The Ohio Nut & Washer Co.
Mingo Junction, Ohio

RIVETING MACHINES
Allen Riveter Co., Chicago, Ill.
Buffalo Forge Co., Buffalo, N. Y.
Chicago Pneu. Tool Co., New York, N. Y.
Grant Mfg. & Mach., Bridgeport, Conn.
High Speed Hammer Co., Rochester, N. Y.
Independent Pneumatic Tool Co., Aurora, Ill.
Keller Tool Co., Grand Haven, Mich
Lemert Engineering Co., Plymouth, Ind.
Tubular Rivet & Stud, Wollaston, Mass.

RAILROAD EQUIPMENT,
Will Reaves Railway Supplies, St. Louis, Mo.

ROTARY VACUUM PUMPS
Leiman Bros., Inc., Newark 5, N. J.

ROUTING MACHINES
Boice Crane Co., Toledo, Ohio
Geo. Gorton Mach. Co., Racine, Wis.
W. B. Knight Machy. Co., St. Louis, Mo.
Onsrud Machine Works, Chicago, Ill.

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Guedcn Co., Audubon, N. J.
Lufkin Rule Co., Saginaw, Mich.
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Micro Switch Div. of First Industrial Corp., Freeport, Ill.

SAFETY GUARDS, Power Presses
Littleford Bros. Inc., Cincinnati 2, Ohio
Searjeant Metal Products, Inc., Mendon, N Y.

SAE WASHERS
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Atlas Press Co., Kalamazoo, Mich.
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Dremel Mfg. Co., Racine, Wis.
R. G. Haskins Co., Chicago, Ill.
Chas. L. Jarvis Co., Middletown, Conn.
Jefferson Mach. Tool Co., Cincinnati, O.
Keller Tool Co., Grand Haven, Mich.
Nedco Tool Co., Waltham, Mass.
Porter Cable Mach. Co., Syracuse, N. Y.
The Rotor Tool Co., Cleveland 12, Ohio
Skilsaw Inc., Chicago, Ill.
Stanley Works, New Britain, Conn.
Stow Mfg. Co., Binghamton, N. Y.
Sundstrand Machine Tool Co., Rockford, Ill
Vonnegut Moulder Corp., Indianapolis 2, Ind.
Walker Turner Co., Plainfield, N. J.

SAWS
Clizbe Bros. Mfg. Co., Plymouth, Ind.
Forsberg Mfg. Co., Bridgeport, Conn.
Simonds Saw & Steel Co., Fitchburg, Mass.

SAWS, Metal Cutting
Simonds Saw & Steel Co., Fitchburg, Mass.

SAW SHARPENERS
Black Diamond Saw Mach., Natick, Mass.
★Covel Hanchett Co., Big Rapids, Mich.
(See Adv. under Knife Grinders)
Foley Mfg. Co., Minneapolis, Minn.
Huther Bros. Saw Co., Rochester, N. Y.
Wardwell Mfg. Co., Cleveland, Ohio

SCREW DRIVERS, Power
The Bodine Corp., Bridgeport, Conn.
Chicago Pneumatic Tool Co., New York 17, N. Y.
Cincinnati Elec. Tool Co., Cincinnati, Ohio

Continued on next page

FLAME CUTTING PROCEDURE

Select the proper burning tip; gas pressures; and cutting speed from the table below. After lighting blowpipe, adjust preheat valves to produce a neutral flame.

Neutral (Pre-heat) Flame: Oxy-acetylene—a clear white flame with the feather drawn up and eliminated. City gas with oxygen —a clear blue flame similar to a gas range; flame length will depend upon existing gas pressures.

Start of the Cut: Let the tip of the neutral flame pre-heat the starting point of the cut to a white heat, then simultaneously set the torch in motion and release the cutting oxygen. After cutting is started, readjust the flame and speed to produce the quality of cut desired.

Faulty Flames: Most flame difficulties arise from dirt lodged in the orifices of the tip—make sure the tip is clean before each cut. Too hot a flame creates beads along the top edge of the cut. Too much oxygen, too slow a speed, or both, produce ragged cutting beneath the top surface. Too little oxygen, too fast cutting, or both, cause excessive drag.

Alloy or Carbon Steels: All steels require the same general type flame and speeds. However, the higher carbon steels require preheating before burning to produce a high quality cut free from surface cracks. Steels of more than .30 carbon, require annealing or flame softening after cutting if the edges are to remain soft.

Heavy Sections: Thicknesses up to one foot can be cut with ordinary equipment; thicker sections usually require special techniques and equipment.

Stainless Steel, Steel Castings, Iron in any form or Non-Ferrous Metals: These metals require special techniques for flame cutting.

FLAME CUTTING TIME AND MATERIAL

Thickness of Metal, Inches	Oxweld Nozzle No.	Cutting Oxygen Drill Size	Cutting Oxygen Pressure*	Linear Cutting Speed**		Consumption Per Hour	
				Machine Cutting In. Per Min.	Hand Cutting In. Per Min.	Oxygen Cu. Ft.	Acetylene Cu. Ft.
1/8	4	60	16-24	22.6-32.0	19.9-29.8	45- 55	7.2- 8.8
1/4	6	53	12-18	20.4-28.4	17.6-25.8	77- 93	8.7-10.7
3/8	6	53	18-26	18.9-26.3	16.0-23.7	95-115	9.7-11.9
1/2	6	53	22-30	17.6-24.6	14.8-22.2	105-125	10.5-12.9
3/4	6	53	26-35	15.4-21.6	13.1-19.8	117-143	12.0-14.6
1	6	53	30-41	13.6-19.4	11.8-18.0	130-160	13.0-16.0
2	8	46	24-32	10.0-14.0	8.6-13.0	185-225	16.2-19.8
3	8	46	35-45	7.8-10.9	6.6- 9.8	240-290	18.5-22.7
4	8	46	45-58	6.4- 8.9	5.2- 7.8	293-357	21.1-25.9
5	8	46	56-70	5.4- 7.4	4.2- 6.4	347-423	23.9-29.3
6	10	39	49-64	4.7- 6.5	3.5- 5.4	400-490	26.5-32.3
8	10	39	65-83	3.7- 4.9	2.6- 4.2	505-615	31.5-38.5
10	10	39	81-103	2.9- 3.8	1.9- 3.2	610-750	36.9-45.1
12	12	31	75-93	2.4- 3.0	1.4- 2.6	720-880	42.3-51.7

Courtesy of The Linde Air Products Company

*Pressure measured at regulator ahead of 50 feet of 3/8" hose.

***Lowest Speeds* and *highest gas consumption* per linear foot are for inexperienced operators, short cuts, dirty or poor material, and hand cutting.

Highest speeds and *lowest gas consumption* per linear foot are for thoroughly experienced operators, long cuts, clean and good material, and machine cutting.

SCREW DRIVERS, Power

Detroit Power Screw Driver, Detroit, Mich.
Independent Pneumatic Tool Co., Aurora, Ill.
Keller Tool Co., Grand Haven, Mich.
Reed-Prentice Corp., Worcester, Mass.
The Rotor Tool Co., Cleveland 12, Ohio
Syntron Co., Homer City, Pa.

SCREW MACHINES, Automatic

Brown & Sharpe Mfg., Providence, R. I.
Cone Automatic Mach. Co., Windsor, Vt.
Foote-Burt Co., Cleveland, Ohio
National Acme Co., Cleveland, Ohio
Jones & Lamson Mach., Springfield, Vt.
Triplex Mach. Co., New York, N. Y.

SCREW MACHINES, Plain and Hand

Acme Mach. Tool Co., Cincinnati, Ohio
Gisholt Machine Co., Madison, Wis.
W. H. Nichols Co., Waltham, Mass.
Rivett Lathe & Grinder Co., Boston, Mass.
Simmons Mach. Tool Corp., Albany, N. Y.
Warner & Swasey Co., Cleveland, Ohio

SCREWS, Cap and Set

Allen Mfg. Co., Hartford, Conn.
Brighton Screw & Mfg. Co., Cincinnati, O.
Dardelet Threadlock Co., New York, N. Y.
Groove Pin Corp., Union City, N. J.
Holo Krome Screw Corp., Hartford, Conn.
Parker-Kalon Corp., New York, N. Y.
Safety Socket Screw Corp., Chicago, Ill.
Triplex Screw Co., Cleveland, Ohio

SCREWS AND BOLTS, Machine

Bristol Company, Waterbury, Conn.
Economy Machine Co., Chicago, Ill.
Lamson & Sessions Co., Cleveland, Ohio

SCREW MACHINE PRODUCTS

Modern Screw Products Co., St. Louis, Mo.

SELF-RETAINING NUTS

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SHAFTS, Flex (See Flex Shaft Equip.)

Acme Tool Co., New York, N. Y.

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Atlas Press Co., Kalamazoo, Mich.
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Cincinnati Shaper Co., Cincinnati, Ohio
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Rockford Mach. Tool Co., Rockford, Ill.
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Hanson-Whitney Co., Hartford, Conn.
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Morey Machy. Co., New York, N. Y.
Pratt & Whitney, West Hartford, Conn.

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Beatty Mfg. Co., Hammond, Ind.
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Excelsior Tool and Machine Co., East St. Louis, Ill.

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The J. F. Kidder Mfg. Co., Inc., Burlington, Vt.
A. Klingelhofer, Inc., New York, N. Y.
Marshalltown Mfg. Co., Marshalltown, Ia.
Niagara Mach. & Tool Co., Buffalo, N. Y.
W. A. Whitney Mfg. Co., Rockford, Ill.

SHEARS, Rotary

E. W. Bliss Co., Brooklyn, N. Y.
Consol. Mach. Tool Co., Rochester, N. Y.
Libert Machine Co., Green Bay, Wis.
Niagara Machine & Tool Works, Buffalo 11, N. Y.
Quickwork-Whiting Corp., Harvey, Ill.

SHIMS

The B. F. Goodrich Co., Akron, Ohio

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Douglas Machy. Co., New York, N. Y.
General Machinery Corp., Hamilton, Ohio

SOLDERING EQUIPMENT

Imperial Brass Mfg. Co., Chicago, Ill.
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★Modern Engineering Co., St. Louis, Mo. (See Adv. Back Cover)
Torit Mfg. Co., St. Paul, Minn.
Wayne Chem. Co., Detroit, Mich.

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GArfield 3954

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THE ESSMUELLER COMPANY
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SPECIAL MACHINERY
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GArfield 3490

The Hamilton Tool Co., Hamilton, Ohio

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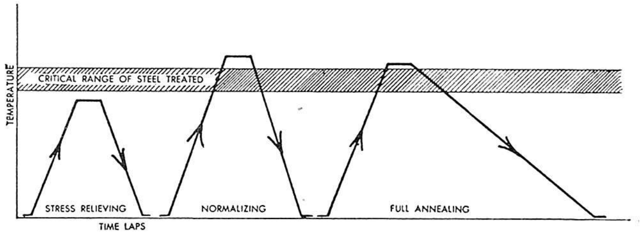
GRand 4580

WELDABILITY OF STEELS—(Cont'd)

Heat Treatment of Welded Structures

In order to insure satisfactory results in welded construction, it is sometimes necessary to augment the welding operation with PRE-heat treatment and/or POST-heat treatment. Depending on conditions, the latter may be a stress relieving, annealing or normalizing treatment. Usually, the standard stress relieving treatment is specified.

Since both annealing and normalizing are effective in lowering residual stresses, they are sometimes confused with the simpler stress relieving form of treatment. The following paragraphs describe each of these processes as well as preheating. Note particularly that annealing and normalizing involve heating to above the critical range, whereas stress relieving consists of heating to just below the range. (See diagram.)



Preheating—Heating the base metal prior to the welding operation to the temperature range 300° to 500° F. Depending on conditions, it may be accomplished by heating in furnace, with torch flame, or by a light "preheating" welding pass.

Effect: It slows down the cooling effect (by heat absorption) of the surrounding base metal, thus lowering stresses and tendency towards hardening and cracking.

Stress Relieving—Heating after welding to approximately 1150° F. or just below the lower critical temperature. Heating and cooling rates should not exceed 300°-350° F. per hour. Holding time one hour per inch of greatest thickness.

Effect: Relieves stresses caused by expansion and contraction, serving to minimize distortion in machining operations, improve ductility and fatigue resistance properties.

Annealing (Full)—Heating to a temperature usually about 100° F. above the upper critical, followed by very slow cooling in furnace. (15°-30° F. per hour.)

Effect: Uniform softness for better machining properties.
Refined and uniform grain structure.
Relieved stresses.
Improved ductility but lowered tensile strength.

Normalizing—Heating to above critical range (usually slightly higher than in case of annealing), followed by cooling in still air at room temperature.

Effect: Dissolution of carbide network in higher carbon steels which is formed on slow cooling from high temperatures.
Refined and uniform grain structure.
Higher strength and hardness but less ductility than same steel annealed.

(Continued)

SPECIAL MACHINERY

Multiple Boring Machine Co., St. Louis, Mo.

Sundstrand Machine Tool Co., Rockford, Ill

The Fred J. Swaine Mfg. Co., St. Louis, Mo.

Swanson Tool & Machine Products, Inc., Erie, Pa.

SPEED REDUCERS

Abart Gear & Mach. Co., Cicero, Ill.

Janette Mfg. Co., Chicago, Ill.
K. O. Lee & Son, Aberdeen, S. D.

Multiple Boring Machine Co., St. Louis, Mo.

SPRINGS, (All Kinds)

Ace Spring Mfg. Co., Inc., New York City, N. Y.

SPROCKETS

Brewer Machine & Mfg. Co., St. Louis, Mo.

STEEL, Aircraft

Bethlehem Steel Co., Bethlehem, Pa.

STEEL, Alloy

Republic Steel Corp., Alloy Steel Div., Massillon, Ohio

STEEL STAMPS

Acromark Corp., Elizabeth, N. J.

The C. H. Hanson Co., Chicago 10, Ill.

J. H. Matthews & Co., Pittsburgh, Pa.
New Method Steel S. Co., Detroit, Mich.
Schwerdtle Stamp Co., Bridgeport, Conn.

The Pannier Corp., Pannier Bldg., Pittsburgh, Pa.

STRAIGHTENING MACHINERY

Sleeper & Hartley, Inc., Worcester, Mass.
U. S. Tool Co., Ampere, N. J.
Watson-Stillman Co., Roselle, N. J.

STUD SETTERS

Chicago Pneumatic Tool Co., New York 17, N. Y.

Independent Pneumatic Tool Co., Aurora, Ill.

Keller Tool Co., Grand Haven, Mich.
Modern Tool Works, Rochester, N. Y.
Titan Tool Co., Fairview, Pa.

SUPERFINISHING, Machines

Gisholt Machine Co., Madison 10, Wis.

SURFACE PLATES

J. C. Busch Co., Milwaukee, Wis.
Challenge Machy. Co., Grand Haven, Mich.
The Hamilton Tool Co., Hamilton, Ohio
Lombard Gov. Corp., Ashland, Mass.
Milliken Mach. Co., West Newton, Mass.

SWITCHES

Micro Switch Div. of First Industrial Corp., Freeport, Ill.

STENCILS, Ready To Use Letters and Numbers

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TAPES, Masking

W. H. Brady Company, Milwaukee, Wis.

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Atlas Press Co., Kalamazoo, Mich.

Boice Crane Co., Toledo, Ohio
Cleveland Tapping Mach., Cleveland, O.
Delta Mfg. Co., Milwaukee, Wis.
Dorman Machine Works, New York, N. Y.
Ettco Tool Co., Brooklyn, N. Y.
Hamilton Tool Co., Hamilton, Ohio
Kaufman Mfg. Co., Manitowoc, Wis.
Procunier Safety Chuck Co., Chicago, Ill.
Rickert-Shafer Co., Erie, Pa.

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Banner Machine Tool Co., St. Louis, Mo.

TESTING MACHINES AND EQUIP.

Detroit Testing Mach. Co., Detroit, Mich.
Modern Collet & Mach. Co., Ecorse, Mich.
Physicists Research Co., Ann Arbor, Mich.
Pyro-Elec. Inst. Co., Detroit, Mich.
Riehle Testing Mach. Div., E. Moline, Ill.
Shore Inst. & Mfg. Co., Jamaica, N. Y.

TEXT, Books, Machinists & Tool Makers

Shields Publishing Co., Books for Machinists and Toolmakers, St. Louis 7, Mo.

THREAD, Rolling Machines

Reed Roller Thread Die Co., Worchester 2, Mass.

THREADING TAPPERS, Hand

Lassy Tool Corp., Plainville, Conn.

TOGGLE-ACTION CLAMPS

Lapeer Mfg. Co., Lapeer, Mich.

TOGGLE-ACTIO PLIERS

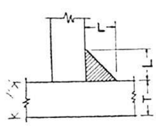
Lapeer Mfg. Co., Lapeer, Mich.

WELDABILITY OF STEELS—

Estimating Electrode Consumption

Figures represent lbs. of heavily coated electrodes required per foot of various sizes and types of welded joints. Weights given are approximate and are based on average welding conditions, accounting for stub end, spatter and coating losses, as well as normal fit-up conditions. Average reinforcement is considered in each case.

Fillet Weld



Size of Fillet=L	Lbs. of Rod Per Linear Ft.	Size of Fillet=L	Lbs. of Rod Per Linear Ft.
1/8	.06	1/2	.81
3/16	.13	5/8	1.23
1/4	.23	3/4	1.76
5/16	.36	1	3.12
3/8	.46		

Plain Butt Weld 50% Penetration

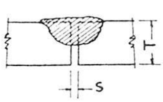


Plate Thickness =T	Space Between =S	Lbs. of Rod Per Linear Ft.
3/16	1/16	0.21
1/4	3/32	0.28
5/16	1/8	0.40

Plain Butt Weld 100% Penetration

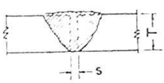


Plate Thickness =T	Space Between =S	Lbs of Rod Per Linear Ft.
1/8	1/16	0.16
3/16	3/32	0.28
1/4	1/8	0.40

"V" Groove Weld

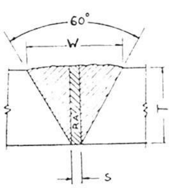


Plate Thickness =T	Lbs of Rod Per Linear Ft.	Width of Weld =W
1/4	0.22+RA**	19/64+S*
5/16	0.34+RA	23/64+S
3/8	0.49+RA	7/16+S
1/2	0.88+RA	37/64+S
5/8	1.36+RA	23/32+S
3/4	1.90+RA	7/8+S
1	3.30+RA	1 5/32+S

*=Space between plates, or Root Opening. **=Rectangular area. See Rectangular Weld table for value corresponding to RA.

Rectangular Welds = R A Values

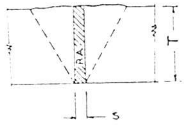


Plate Thickness =T	Lbs. of Rod per Linear Ft. for R A — S=Space Between Plates: 1/8"	5/32"	3/16"	1/4"	5/16"	3/8"	1/2"
1/4"	0.20	0.25	0.30	0.41	0.51	0.61	
3/8"	0.29	0.36	0.43	0.57	0.71	0.86	1.14
1/2"	0.37	0.46	0.55	0.73	0.92	1.10	1.47
5/8"	0.45	0.56	0.67	0.90	1.12	1.34	1.79
3/4"	0.53	0.66	0.80	1.06	1.33	1.59	2.12
1"	0.69	0.87	1.04	1.38	1.73	2.08	2.77

"U" Groove Weld

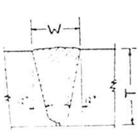


Plate Thickness =T	Lbs of Rod Per Linear Ft.	Width of Weld =W	Plate Thickness =T	Lbs of Rod Per Linear Ft.	Width of Weld =W
3/4	2.72	49/64	2	11.17	1 19/64
1	4.08	7/8	2 1/4	13.38	1 13/32
1 1/4	5.62	63/64	2 1/2	15.72	1 1/2
1 1/2	7.30	1 5/64	2 3/4	18.25	1 39/64
1 3/4	9.08	1 3/16	3	21.00	1 23/32

TOOLS, Carbide
Adamas Carbide Corp., Harrison, N. J.
Carboloy Co., Inc., Detroit, Mich.
The Gairing Tool Co., Detroit 32, Mich.
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McKenna Metals Co., Latrobe, Pa.
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Michigan Tool Co., Detroit, Mich.
Morse Tool Co., Detroit, Mich.
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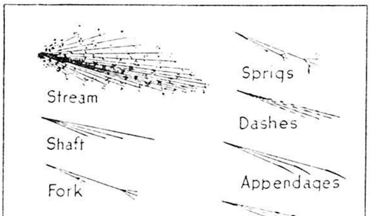
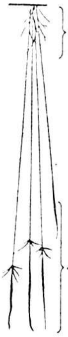
IDENTIFYING METALS BY SPARK TESTING

Spark tests should be made on a high speed power grinder, and the specimen should be held so that the sparks will be given off horizontally. For most accurate results, the sparks should be examined against a dark background, preferably in a dark corner of the shop.

The color, shape, average length, and activity of the sparks are details which are characteristics of the material tested. Spark testing can be a very accurate method of identifying metals but it requires considerable practice and experience to become an expert. Several common sparks are given in the table. If the operator learns the technique for identifying these metals readily, he will soon be able to expand his experience to include others by observation and comparison with the sparks from known samples.



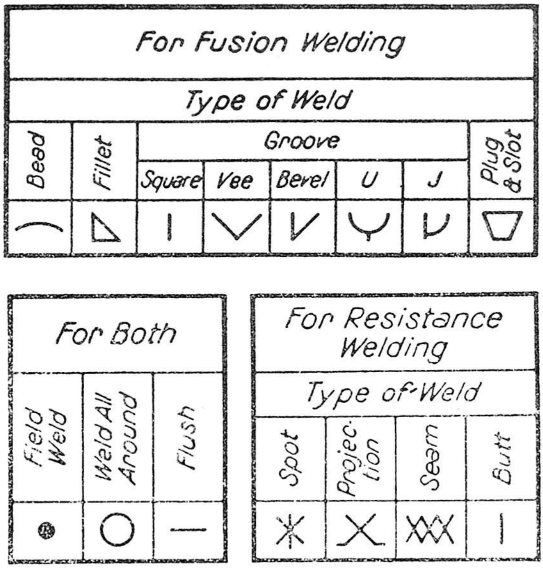
Meaning of the terms used in spark testing

Wrought Iron	Low-Carbon Steel*	High-Carbon Steel
 Color - straw yellow. Average stream length with power grinder - 65 in. Volume - large. Long shafts ending in forks and arrowlike appendages. Color - white	 Color - white. Average length of stream with power grinder - 70 in. Volume - moderately large. Shafts shorter than wrought iron and in forks and appendages. Forks become more numerous and sprigs appear as carbon content increases	 Color - white. Average stream length with power grinder - 55 in. Volume - large. Numerous small and repeating sprigs
Alloy Steel**	**White Cast Iron**	**Gray Cast Iron**
 Color - straw yellow. Stream length varies with type and amount of alloy content. Shafts may end in forks, buds or arrows, frequently with break between shaft and arrow. Few, if any, sprigs. Color - white	 Color - red. Color - straw yellow. Average stream length with power grinder - 20 in. Volume - very small. Sprigs - finer than gray iron, small and repeating	 Color - red. Color - straw yellow. Average stream length with power grinder - 25 in. Volume - small. Many sprigs small and repeating
	Malleable Iron	**Nickel*****
*These data apply also to cast steel. **Spark shown is for stainless steel. ***Monel metal spark is very similar to nickel.	 Color - straw yellow. Average stream length with power grinder - 30 in. Volume - moderate. Longer shafts than gray iron ending in numerous small, repeating sprigs	 Color - orange. Average stream length with power grinder - 10 in. Short shafts with no forks or sprigs

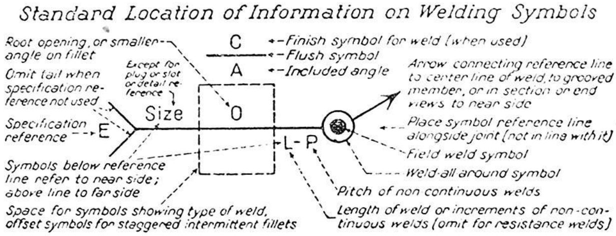
Courtesy of The Linde Air Products Company

Welding Symbols

Adopted As Standard by the American Welding Society, 1937

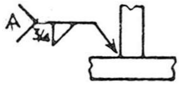


Standard Location of Information on Welding Symbols

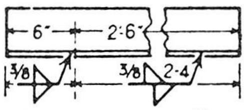


WELDABILITY OF STEELS—(Cont'd)

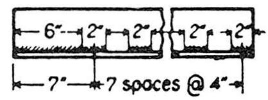
Significance of Typical Combinations



Indicates continuous $\frac{3}{4}''$ fillet weld on near side, made under shop's own specification A. →

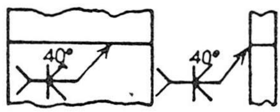


Spacing indicated →



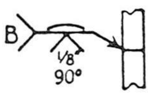
$\frac{3}{8}''$ fillet weld both sides for 6″. Welds on both sides are same size unless noted.

$\frac{3}{8}''$ fillet welds 2″ long, 4″ on centers, opposite sides staggered.

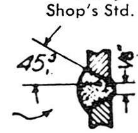


When one member only is to be grooved arrows point to that member, thus:

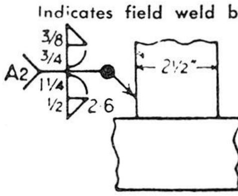
Shop's Std.



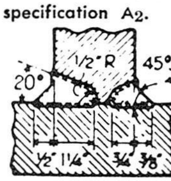
Indicates plates bevelled at root opening $\frac{1}{8}''$ on assembly, bead deposited on root side.

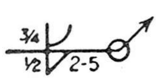


Indicates field weld both sides, by shop's specification A_2.



Vertical plate: double J groove. Weld far side: continuous. Near side: 2″ long, 6″ on centers.





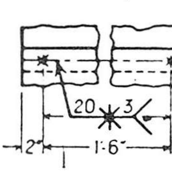
Significance: Weld all around (encircling member as far as possible). Near side: $\frac{1}{2}''$ fillet, 2″ long, 5″ on centers. Far side: plate has $\frac{3}{4}''$ J groove (shop's standard), continuous weld.

Read symbols from bottom and right-hand side of drawing; place numerical data on vertical reference lines so reader is properly oriented.

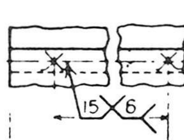
Significance: Square edges on plates clearing $\frac{1}{8}''$, welded from near side, $\frac{1}{4}''$ penetration required.

Significance: Closely abutting plates with U groove $\frac{7}{8}''$ deep, near side chipped smooth.

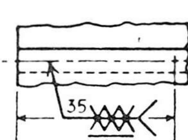
Symbols govern to break in continuity of structure or to extent of hatching or dimension lines. Strength of resistance welds in hundreds of pounds noted instead of size:



2000-lb. spot welds, at 3″ centers.



1500-lb. projection welds, at 6″ centers.



3500-lb. seam weld, 9″ long, flush near side.

(Continued)

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M-B Products Co., Detroit, Mich.

VALVES, Air Safety Check

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Yost Mfg. Co., Meadville, Pa.

VISES, Combination Pipe

The Vanderman Mfg. Co., Willimantic, Conn.

VISES, Drill Press

J. E. Martin Machine Works, Springfield, Ohio

VISES, Machine

Acme Tool Co., New York, N. Y.
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Sales Service Machine Tool Co., Saint Paul W4, Minn.

VISE-WRENCHES

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WELDERS, Arc

Automotive Supply Co., Appleton, Wis.
Borm Mfg. Co., Elgin, Ill.
Ergolyte Co., Philadelphia, Pa.
Giant Grip Mfg. Co., Oshkosh, Wis.
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Hobart Bros. Co., Troy, Ohio
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Magic Electro Welder, New York, N. Y.
National Cylinder Gas Co., Chicago, Ill.

WELDERS, Gas

Air Reduction Sales, New York, N. Y.
Linde Air Prod. Co., New York, N. Y.
Metal & Thermit Corp., New York, N. Y.
National Cylinder Gas Co., Chicago, Ill.
*Modern Engineering Co., St. Louis, Mo. (See Adv. Back Cover)

WELDERS, Spot

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Alphil Spot Welder Co., New York, N. Y.
Amer. Elec. Fusion Corp., Chicago, Ill.
Dyer Welder & Engr. Co., Kansas City Mo.
Ideal Mfg. Co., Des Moines, Iowa
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Una Welding Co., Cleveland, Ohio
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(See CYLINDERS)

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Duro Metal Prod. Co., Chicago, Ill.
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Plomb Tool Co., Los Angeles, Calif.
Ridge Tool Co., Elyria, Ohio
Trimont Mfg. Co., Roxbury, Mass.
J. H. Williams Co., New York, N. Y.
Southern Machinery Corp., Lakeland, Fla.
Bill Lindsley Machinery Co., Dallas, Texas
McGee & Hogan Machine Works, Salt Lake City, Utah
Ariz. Machinery Co., Phoenix, Ariz.
Cragin & Co., Seattle, Wash.
Precision Machine Works, Tacoma, Wash.
Miller-Knuth Mfg. Co., Omaha, Neb.
Industrial Machine Co., Oklahoma City, Okla.
Southeastern Foundries, Inc., Atlanta, Ga.

MAGNAFLUX TESTS

The Magnaflux Test is generally used to detect the presence of fine cracks, seams and other imperfections, too small to be seen by the naked eye, but which might develop local stress and cause ultimate failure in a finished part. Sometimes it is possible to detect certain defects, which are actually under, yet near the surface of the metal, and which might not otherwise be detected. Magnaflux inspection does not harm the part being tested.

Parts being tested are magnetized by one or more methods, depending on their size, shape and final application. In this condition they are a conductor of a magnetic flux. If interruptions occur in the path of the flux, a local flux leakage field is produced. When fine particles of ferro-magnetic powder come in contact with the specimen they are attracted to the local leakage field and thus outline its size and location.

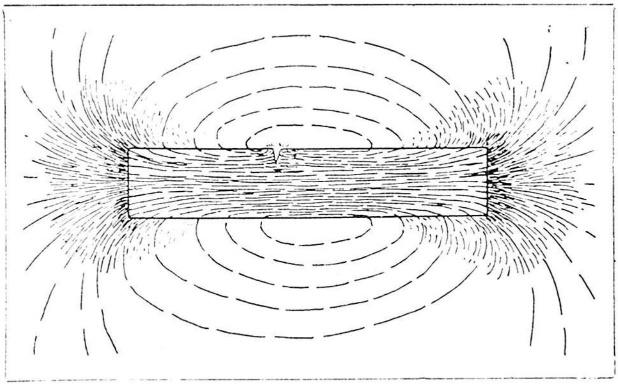
Ferro-magnetic powder may be applied by: dusting on dry; dipping the parts in an oil bath containing the powder in suspension; or pouring this oil over the parts.

The creation of a flux leakage field requires an interruption in the flow of magnetic flux. The interruption or discontinuity, to be detected, must occur at an angle (preferably as close to 90° as possible) and not parallel to the direction of the flux flow. When the magnetic flux is traveling from one end of a bar to the other, the longitudinal surface discontinuities or seams are not clearly indicated, whereas, a crack extending around the bar across the magnetic flow would be readily revealed. Since the direction of magnetic flow, the amount of current used, the method of applying the ferro-magnetic powder, and the interpretation of the indications, all contribute to this highly specialized test, considerable experience is essential for interpreting results.

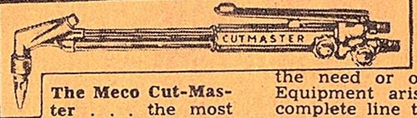
It is useless to Magnaflux-test the surface of a bar which is later to be machined. Surface defects indicated by the test might be eliminated while other defects, beneath the surface, might not be revealed in the test, but might show up when the bar is machined.

Because of the variations in testing, any indications that are used as a basis for acceptance or rejection of a part should be interpreted with respect to their number, size and location as well as the stresses to which the part will be subjected. The details of the Magnaflux Test and interpretation should be clearly agreed upon between the user and the steel supplier in advance of production.

(Diagram of magnetic field in and around a magnetized round sample. Note Magnetic flux leakage caused by surface discontinuity.)



Meco Everything for Welding



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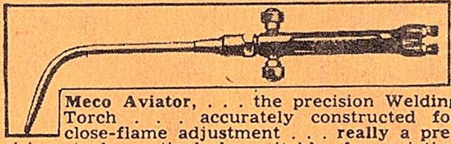
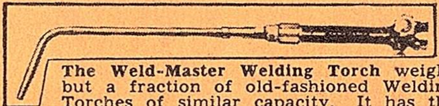
The Meco Cut-Master . . . the most popular cutting torch on the market . . . more torch in the way of efficiency and economy of operation than its modest price would indicate.



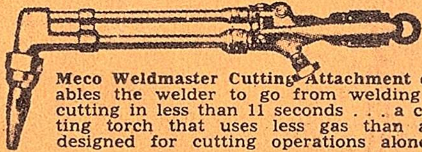
Meco Aviator, . . . the precision Welding Torch . . . accurately constructed for close-flame adjustment . . . really a precision tool, particularly suitable for aviation work.

The Meco Type-A Heavy-Duty Cutting Torch . . . is the fastest-cutting torch made . . . the torch that can be handled with utmost accuracy in gas cutting for fabrication. A complete range of Cutting Heads, including a straight head, are available for the Meco Type-A. As a result, it is a versatile and flexible cutting torch of greatest possible usefulness throughout the shop . . . the finest torch that money can buy.

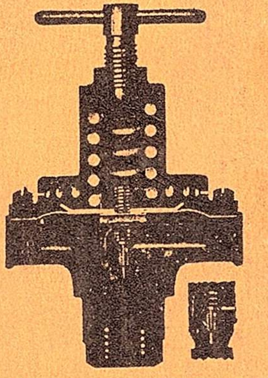


The Weld-Master Welding Torch weighs but a fraction of old-fashioned Welding Torches of similar capacity. It has the famous, exclusive Circle Mixer and spring tension needle valve. The full gooseneck tips represent an advanced construction and are highly recommended for general welding practice.

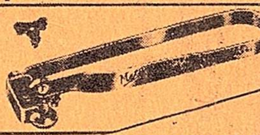
The Super Weld-Master Welding Torch is a heavy-duty torch for heavy-duty welding. Equipped with the famous Circle Mixer, which assures a long, hot flame . . . spring tension needle valves, and all the other exclusive features of the Meco Weld-Master Torches.



Meco Weldmaster Cutting Attachment enables the welder to go from welding to cutting in less than 11 seconds . . . a cutting torch that uses less gas than any designed for cutting operations alone.



Meco Safe-T-Chek Regulators . . . (left). Here is shown a cutaway view of a Meco Safe-T-Chek Regulator. The small inset shows the Safe-T-Chek device which operates in such a way so as to eliminate all hazards of explosion . . . this is to be found only on Meco Regulators and is an exclusive Meco patent.



Meco Tripl - Flint Lighter . . . lights the first time every time. Just a small item in the Meco line but indicative of the rugged construction and highest quality, built into every Meco product . . . a heavy-duty lighter that will give a life time of service and carries 3 large flints, mounted in the holder for immediate reserve . lighter and 3 flints 75c

Before purchasing Gas Welding Equipment of any kind, write for a copy of the Meco Catalog. Meco Equipment is at its best in direct comparison with other types of equipment. Wherever possible, we shall be glad to demonstrate Meco Equipment in your plant or shop.

Modern Engineering Co. - Acetylene Gas Co.

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